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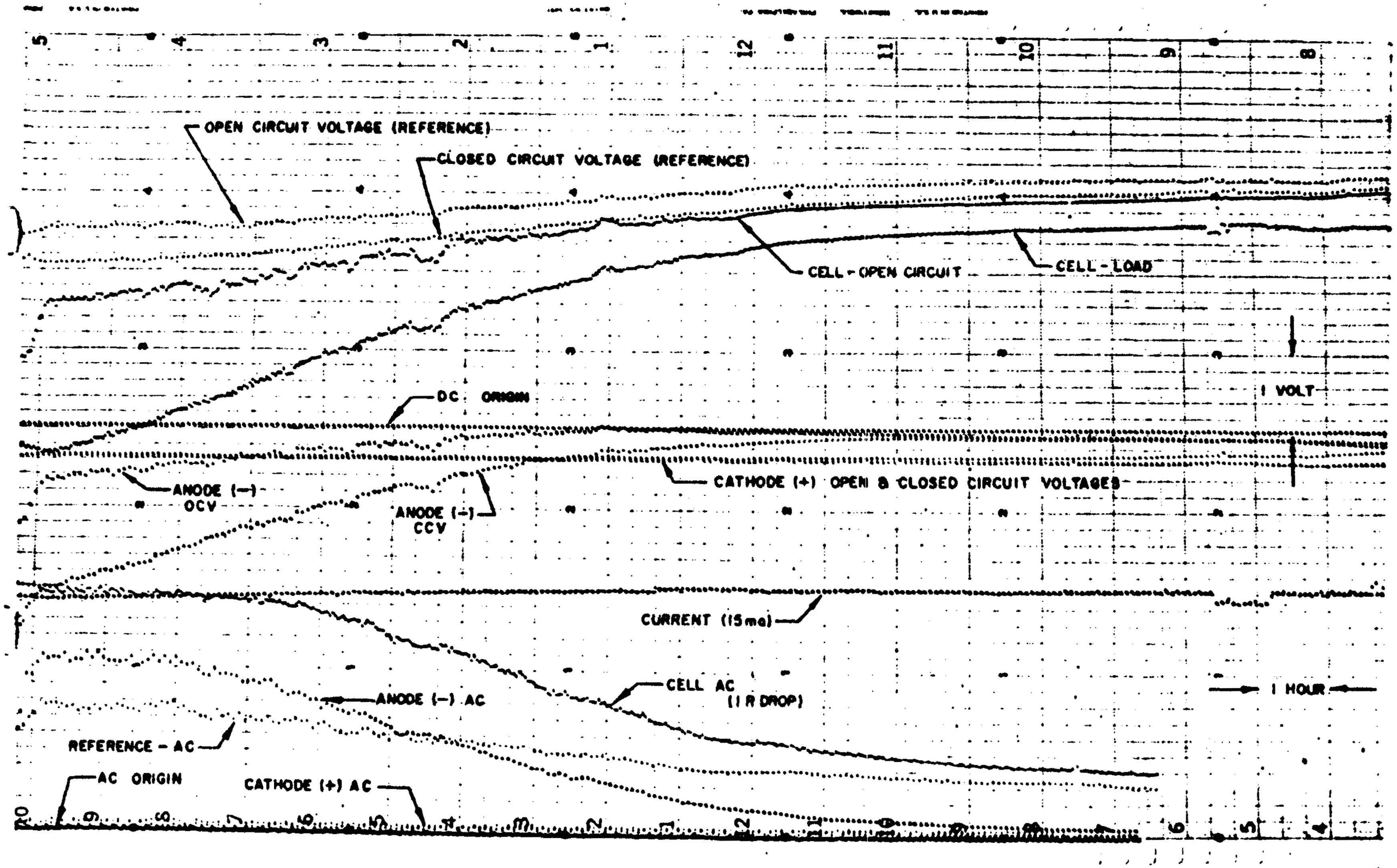
PART A

PROGRAM REVIEW

About 100 years ago Leclanché invented his device which we all know as the "dry cell" or "flashlight battery." Despite a century of study and usage, nearly all batteries today are based upon the same solvent—water! Our endeavors are aimed at examining other solvents in order to develop a higher energy battery.

The study of electrochemical cells is complicated by a general lack of knowledge concerning electrodes in solvents other than water. Numerous techniques are available for measuring the properties of electrodes such as half cells, interrupted or chopped loads, anode controlled cells, cathode controlled cells, etc. Normally, the application of these techniques requires the fabrication, testing, and involved analysis of many special, carefully constructed cells. We have decided to attempt to accelerate the study of the electrochemical systems revealed by the solvent-oriented battery energy equation by means of automatic, cell discharge and complex recording equipment. This equipment was designed and constructed during the last quarter. Details of its functions are presented in this report. Figure I, page 2, is a photograph of the recording of the performance of the first non-aqueous cell tested with this Research Cell Recorder.

A comprehensive approach has been evolved to estimate the practical limits of many different solvents. In the evolution of this approach, the concept of the role of the solvent was materially extended to include not only the liquid forming the basis of the electrolyte, but also the atmosphere in contact with this electrolyte. The solvent-atmosphere concept introduces an additional degree of control over the chemical and physical factors affecting battery performance and raises our estimate of possible, useful cell combinations substantially.



LIVINGSTON ELECTRONIC CORPORATION

RESEARCH CELL RECORDING No. 1

This approach includes not only the theoretical tools for the screening of atmosphere-solvent-solute electrolytes on a figure of merit basis, but also the evolution of a functioning system for the automated collection of the numerour physico-chemical measurements required.

While the actual construction of batteries in each system might be preferable to a synthesis of cells and evaluation thereof by theoretical means, the number of individual tests required for even sparse sampling by constructing conventional cells would necessarily restrict the area of investigation to a relatively few systems of undetermined value.

The data being collected by the present approach are so numerous that recourse has been made to computer calculation and machine presentation of the figures of merit. Even using computer techniques, we have resigned ourselves to reporting less than a tenth of the total data collected by the automatic recording equipment. Previously, only token data have been included in the reports due to the manual computational load. However, manual computation was desirable as a forerunner to scale-up of data production.

Previous to this quarter, the solvent-oriented battery energy equation had indicated the following solvents as being capable of delivering greater than 200 watt hours per pound:

1. Water
2. Ammonia
3. Butyrolactone

The emergence of water as a solvent capable of greater than 200 watt hours per pound was unexpected and depends upon effective use of two ion exchange membranes to allow for alkaline anolytes and acid catholytes (a desalination cell in reverse). Considerable progress has been made recently with respect to availability of ion exchange membranes for use in aqueous systems. However, electrodes capable of providing three volts are apparently lacking when water is the solvent. Electro-pulse catalysis may serve to supply the missing cathode and this is being investigated.

The resistance of ammonia solutions to reduction by alkali metals and their high conductivity qualified liquid ammonia as a fertile area for study. The difficulty here, as in most cases, is the development of a suitable cathode.

Butyrolactone was indicated by the specific resistance-decomposition potential data as having a figure of merit greater than 200 watt hours per pound. Conventional battery technique is being applied to this solvent, and numerous unit cells have been tested.

Machine computation and presentation of the figures of merit as a function of solvent, solute, and various ligand atmosphere pressures have indicated favorable new areas for specific study. Where favorable figures of merit were obtained, some indication of the necessary electrodes and discharge rate for optimum performance are provided by the solvent-oriented battery energy equation.

The most recent calculations indicate several new solvent-solute-atmosphere combinations with satisfactorily high figures of merit:

4) N, N-Dimethylformamide (DMF) + $AlCl_3$, KI + mild NH_3 atmosphere
5) as received N, N-Dimethylformamide + NaI, KI
6) Pyridine + LiF + full NH_3 atmosphere
7) N-Methyl-2-Pyrrolidone + KSCN, KBr, $(CH_3)_4NI$ + CO_2 atmosphere
8) Acetonitrile + $(CH_3)_4NCl$ + mild NH_3 atmosphere
9) as received Actonitrile + LiCl
10) Dimethyl Sulfoxide + NaI, $NaCO_2 CCl_3$ + SO_2 atmosphere
11) as received Dimethyl Sulfoxide + $Al_2(SO_4)_3$, LiCl

Concerning the importance of impurities in non-aqueous solvents, Harris[1] reports that CdI_2 is highly soluble in desiccated propylene carbonate of 98 per cent initial purity. The solubility in carefully purified propylene carbonate (>99%) is low, only 0.166 grams per 100 grams of solvent. Harris continues by pointing out that the solubility of KI is negligably affected by purification of the desiccated solvent.

Many organic solvents decompose under the influence of the salts dissolved therein.

One of the significant developments of the program to date has been to develop the control of impurities usually present in the solvents. Operation of a battery further enhances the generation of by-product impurities. The collection and interpretation of extensive data rather than intensive data may provide for the construction of higher energy density batteries using normal purity ranges.

Considerable data has accumulated for additional electrolyte systems. A key punch has been installed at this facility, and the accumulated data will be selectively transferred to punch cards. Since the computer program is operational, we anticipate prompt completion of interpretation; and additional systems of high figures of merit resulting from these remaining computations will be assigned task numbers for cell testing. It is next planned to utilize the specific conductivity-decomposition voltage equipment to test cells requiring special atmospheres.

At the beginning of the program we viewed the overall objective as including approximately 120 electrochemical combinations:

$$(10 \text{ solvents}) * (12 \text{ representative solutes}) = 120$$

---

[1]W. S. Harris, Electrochemical Studies in Cyclic Esters, UCRL - 8381, Thesis (1958).

The introduction of the ligand-atmosphere concept served to broaden the number of possible solvents and to increase the number of electrochemical systems directly to 2,400 systems:

(20 solvents) (12 rep. solutes) (10 atmospheres) = 2,400

The use of the solvent-oriented battery equation, the specific resistance-decomposition potential recording equipment, and computer evaluation have served to cover 263 electrochemical combinations of which perhaps ten are indicated for intensive study by construction and testing of batteries.

Materials testing has also been a subject of continuing effort throughout this work. Compatibility with a solvent is affected by solutes and ligand atmospheres as well. Hence, numerous material tests are reported in the presence of these three factors.

PART B

QUANTITATIVE DESCRIPTION OF PROGRESS

I. SPECIFIC RESISTANCE AND DECOMPOSITION POTENTIAL STUDIES

(a) Theoretical. The function of the solvent-oriented battery energy equation is to properly assign the relative importance of electrolyte specific resistance and the ability of the electrolyte to withstand both anodic and cathodic decomposition.

With respect to the derivation of the equation[2], one additional change has been instituted. The use of platinum (or other noble metal) is presently necessary for a uniform evaluation of both anodic and cathodic overvoltage in widely differing non-aqueous solutions. It is also overly conservative with respect to corrosion evaluation. Hence, the two factors of 10 introduced for corrosion and shelf life will be discontinued to compensate for the catalytic nature of the smooth platinum electrodes. Equation (13) of the Second Quarterly Report, page 13, takes the following form as a result of these considerations where L is set at 1/5 cm:

$$Y = XFe^{0.4X-5.5}\left(1-2\sqrt{\frac{R}{5X}}\; e^{(X-C)/2}\right) \tag{1}$$

This form of the solvent-oriented battery energy equation is being used in computer evaluation of the decomposition and specific resistance data. The maximum value of Y, the figure of merit for the system, is reported directly from the computer print-out. A criterion of 500 watt hours per pound of net electrode reactants will be applied to results obtained from equation (1). Previously reported figures of merit were intended for a criterion of 200 watt hours per pound.

(b) Measurements. Conductivity cell studies of specific resistance and Tafel constants for about 100 solvent-solute-atmosphere systems have

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[2] See Second Quarterly Report, starting page 11.

been conducted since the last quarterly report; these systems are included in Table I, pages 9-15, which indexes the materials testing and specific resistivity-decomposition potential measurements to date. The most recent cell design is shown in Figure II, page 16. The completion of the nine-channel strip chart recorder has facilitated these measurements. Figure III, page 17, shows a view of this equipment; and a section of a recorder chart is shown in Figure IV, page 18.

OR NO ATMOSPHERE

AND DECOMPOSITION VOLTAGE MEASUREMENTS

NOTE: The asterisk denotes systems which have been tested. Most of the data have been compu ted, and the results are included in this report.

	$(CH_3)_4NCl$ + $NH_2OH.HCl$	KBr	KF	KI	KSCN	LiF	LiCl	LiCl + $Al_2(SO_4)_3$	$MgSO_4$	NaBr	NaCl	NaI	$MgBr_2$	$NH_2OH.HCl$
1		*		*		*	*		*					
2														
3							6-31							
4		*				*	*					*		
5														
6		*		*		*	*					*		
7														
8		3-30	3-35			3-35	3-30			3-30				
9														
10		3-32	3-36			3-36	3-32		6-26	3-32				
11		6-26					6-26							
12		*		*	*	*	*					*		
13							3-33			3-33				
14														
15							6-30							
16		3-32					3-32			3-32				
17														
18		*		*		*	*		*	*		*		
19		*				*	*							
20														
21	3-37	3-31								3-31	3-37			
22		3-34					3-34			3-34				
23							3-33			3-33				
24														
25														
26														
27														
28		3-33					3-33			3-33				
29							6-30							
30														
31		3-31	3-35			3-35	3-31			3-31				
32		*				6-32	6-33					*		
33		3-32					3-32			3-32				
34		6-30					6-30							
35		*				*							*	*

OR NO ATMOSPHERE Continued

AND DECOMPOSITION VOLTAGE MEASUREMENTS

NOTE: The asterisk denotes systems which have been tested. Most of the data have been computed, and the results are included in this report.

	$(CH_3)_4NCl+NH_2OH.HCl$	KBr	KF	KI	KSCN	LiF	LiCl	$LiCl+Al_2(SO_4)_3$	$MgSO_4$	NaBr	NaCl	NaI	$MgBr_2$	$NH_2OH.HCl$
36														
37		3-31	3-36			3-36	3-31		6-28	3-31				
38		6-28					6-28							*
39		* *		*	*	*	*							
40														
41		3-32					3-32			3-32				
42														
43		6-36		6-31		6-36	6-30							
44							6-36							
45														
46														
47		3-30	3-35			3-35	3-30			3-30				
48		6-25					6-25							
49														
50		3-31	3-36	6-33		6-34	3-31	3-36	6-29	3-31		6-35		
51		6-35					6-28							
52		*					6-34							
53		*			*	*	*			*	*	*	*	
54														
55		3-30	3-35			3-35	3-30			3-30				
56		6-27				*	6-27							
57														
58						*	*							
59														
60		6-29					6-29							
61		*				*	*							
62														
63							3-33							
64		3-34					3-34			3-34				
65														
66						*	*							

TABLE I-A - AMMONIA ATMOSPHERE

INDEX - (a) MATERIALS TESTING; (b) RESISTIVITY AND DECOMPOSITION VOLTAGE MEASUREMENTS

NOTE: The first entry refers to the report number; the second refers to page number.

NOTE: The asterisk denotes systems which have been tested. Most of the data have been computed, and the results are included in this report.

SALTS: / SOLVENTS:		NONE	$AlCl_3$	AlF_3	$Al_2(SO_4)_3$	$(CH_3)_4NCl$	KBr	KI	LiF	LiCl	$MgSO_4$	NaBr	NaI	$(CH_3)_4NI$	$NH_2OH.HCl$
Acetonitrile	b		*	*	*	*	*	*	*	*	*				
Amberlite LA-1	a	7-13	7-13			7-13	7-13		7-13	7-13			7-13		
Amberlite LA-1	b	*	*	*		*	*		*	*			*		
Ammonia, liquid	a	3-27													
Ammonia, liquid	a	6-68													
Butyrolactone	b	6-26	6-26			6-26	6-26			6-26	6-26				
Cyclohexanone	b		6-32							6-30					
N, N-Dimethylformamide	b	*	*	*	*	*	*	*	*	*	*	*	*		
2-Ethanolpyridine	a	7-12	7-12			8-20	8-20		7-12	8-20			8-20		
2-Ethanolpyridine	a								8-20						
2-Ethanolpyridine	b		*	*		*	*		*	*					
Genesolv-D	b	*				*	*		*					*	*
N-Methyl-2-Pyrrolidone	b	6-27	6-28							6-28	6-28				
Petroleum Ether	b	6-30								6-30					
n-Propylamine	b	6-25				6-25	6-25			6-25					
Propylene Carbonate	b	6-28	6-29							6-28	6-29				
Pyridine	a	8-20	8-20			8-20									
Pyridine	b	6-27	*			6-27	6-27		*	6-27					
Toluene	b	6-29	6-29			6-30	6-29			6-29					

TABLE I-B - SULFUR DIOXIDE ATMOSPHERE

INDEX - (a) MATERIALS TESTING: (b) RESISTIVITY AND DECOMPOSITION VOLTAGE MEASUREMENTS

NOTE: The first entry refers to the report number; the second refers to page number.

NOTE: The asterisk denotes systems which have been tested. Most of the data have been computed, and the results are indicated in this report.

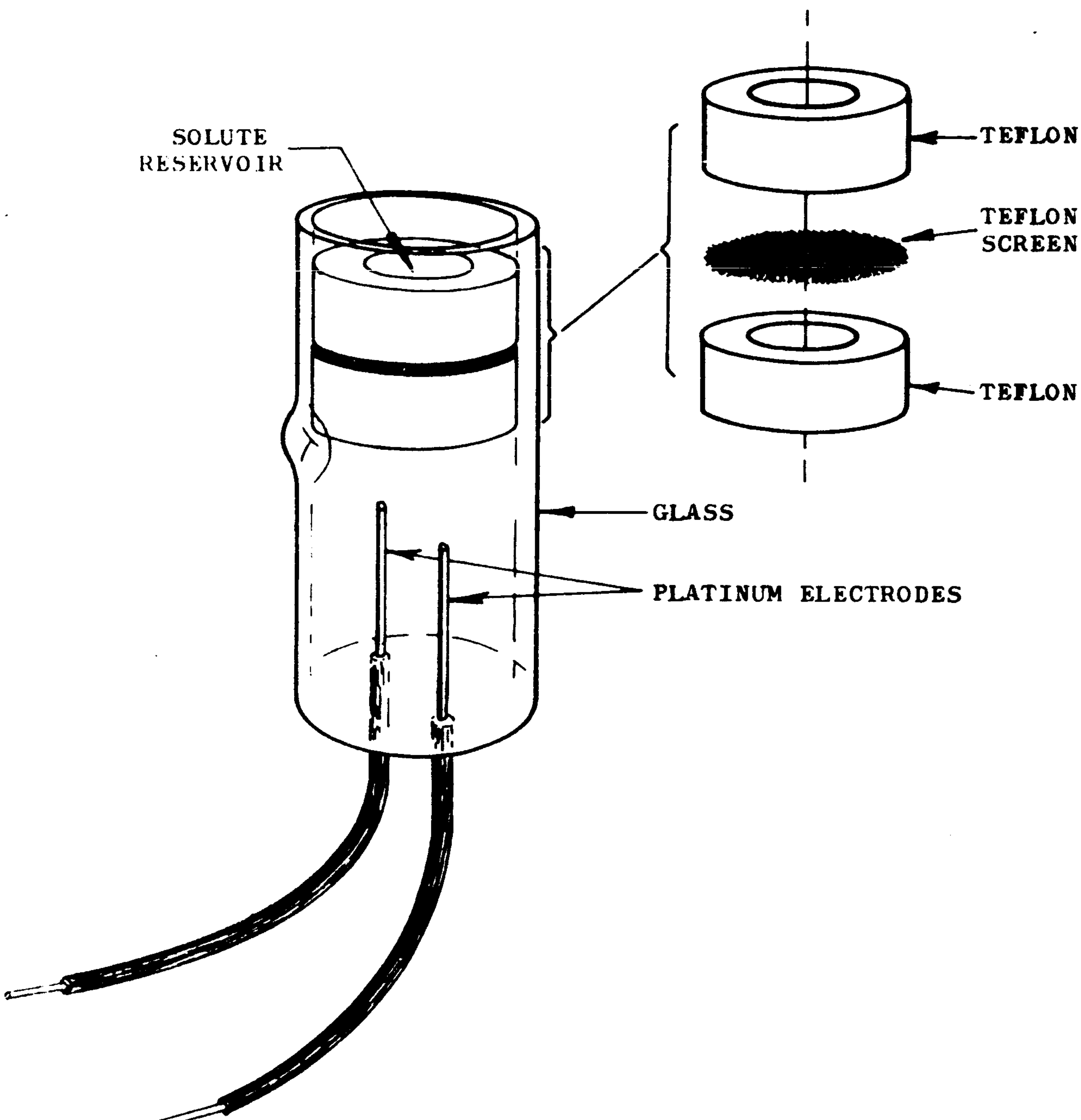
SALTS:		NONE	$AlCl_3$	AlF_3	$(CH_3)_4NCl$	KBr	KI	LiF	LiCl	NaI
SOLVENTS:										
Benzene	a	7-12	7-12		7-12	7-12		7-12	7-12	7-12
Benzene	b	*	*	*	*	*	*	*	*	*
iso-Propylamine	b		6-32		*	*		6-32	6-33	*
Propylene Carbonate	a	6-70	6-70			6-70		6-70	6-70	
Propylene Carbonate	b	6-33	6-35		6-33	6-35	6-33	6-34	6-34	6-35
Propylene Carbonate	b				6-36					
Petroleum Ether	b	6-36	6-36		6-31	6-36	6-31	6-36	6-36	
Tetrahydrofuran	b		*					*	*	
Toluene	b		*	*	*	*		*	*	
Water	b		*					*	*	

TABLE I-C - CARBON DIOXIDE ATMOSPHERE

INDEX - (a) MATERIALS TESTING; (b) RESISTIVITY AND DECOMPOSITION VOLTAGE MEASUREMENTS

NOTE: The asterisk denotes systems which have been tested. **Most of the data have been comp uted, and the results** are indicated in this report.

SALTS:		NONE	$AlCl_3$	AlF_3	$Al_2(SO_4)_3$	$(CH_3)_4NCl$	KBr	KI	KSCN	LiCl	LiF	NaBr	NaCl	NaI	$MgBr_2$	$(CH_3)_4NI$	$NH_2OH.HCl$
SOLVENTS:																	
Butyrolactone	b	*	*	*	*	*	*	*	*	*	*			*			
N-Methyl-2-Pyrrolidone	b		*	*	*	*	*			*	*					*	*
N-Methyl-2-Pyrrolidone	b		*	*	*		*	*	*								
Propylene Carbonate	a	*															
Propylene Carbonate	b	*	*	*	*	*	*		*	*	*	*	*	*	*		
Propylene Carbonate	b	*					*										



CONDUCTIVITY CELL

FIGURE II

FIGURE III

NINE CHANNEL STRIP CHART RECORDER

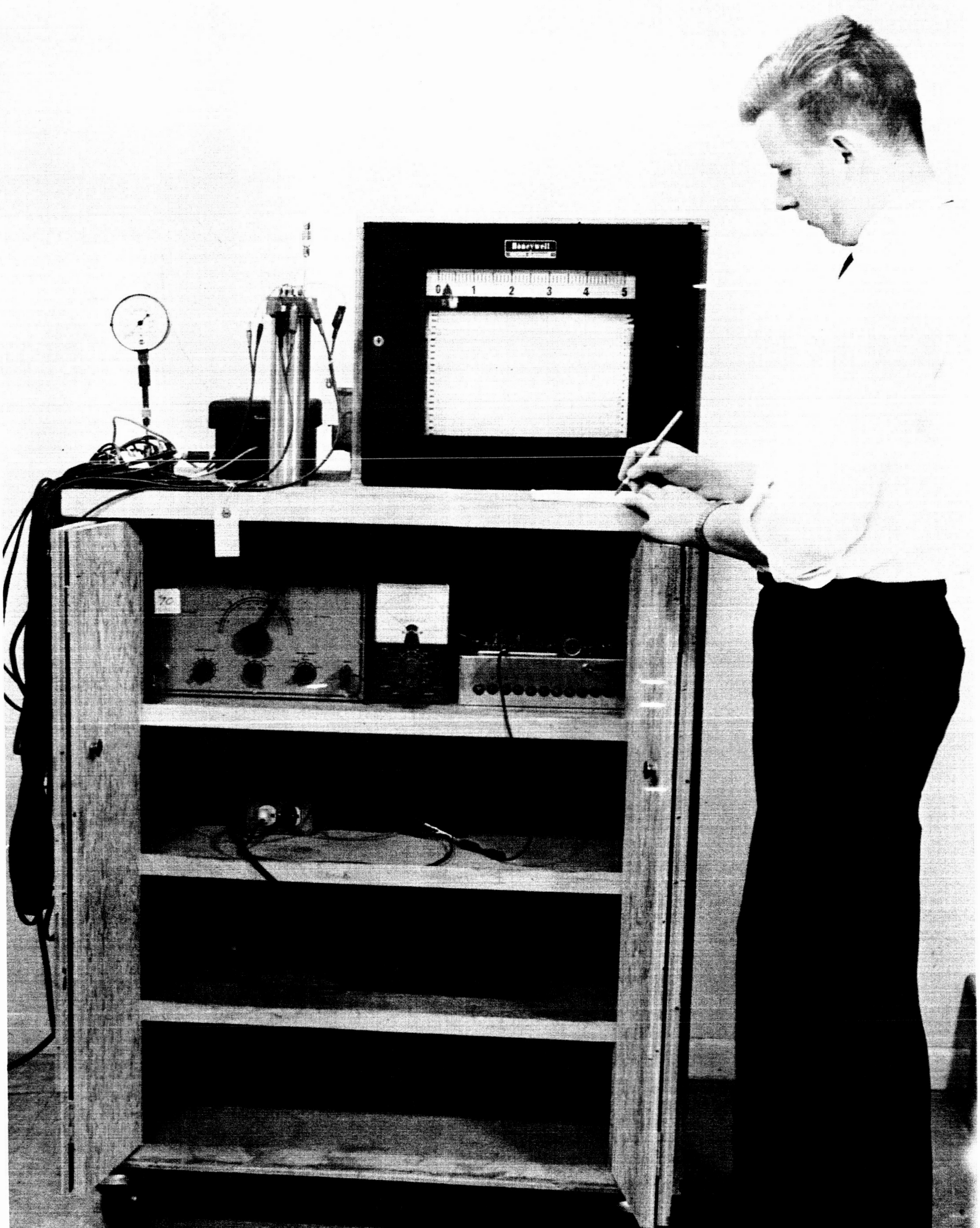
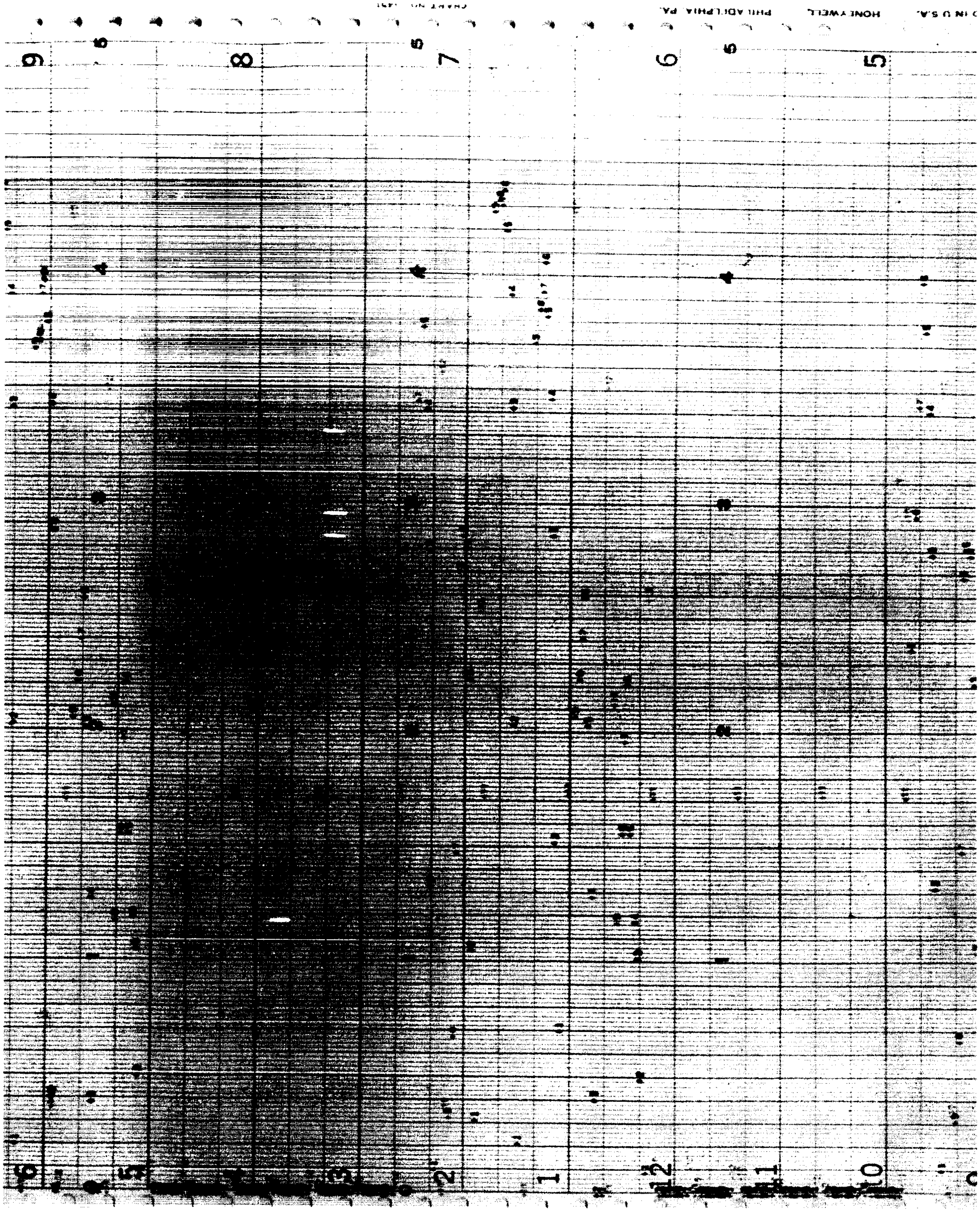


FIGURE IV
SECTION OF RECORDED CHART



In order to evaluate the effect of polarization on the conductivity of the electrolytes being studied, the new data gathering pattern provides cell resistance readings obtained under the condition of 1,000 cps ac superimposed on the maximum dc potential. In addition, specific resistance readings are obtained as before with 1,000 cps ac alone applied across the cell terminals. Although only a small amount of data has been obtained by this method, it appears that, in some instances, the polarization condition affects the specific resistance readings of the solution. This may provide for the clarification of certain anomalies in the Tafel data.

(c) Computation and Interpretation of Data. Considerable progress has been made with respect to machine computation of the specific resistance and decomposition potential data. Figure V, page 25, is a logic diagram or computer flow chart for the initial coverage of the data. The data from the strip chart, Figure IV, page 18, is transferred to a data sheet (see Figure VI, page 26) and then to punch cards which are subsequently fed into the computer.

In compiling the data tables, the computer first reads the title cards which identifies the system under study. These cards are reproduced immediately and call forth a column title or header card.

The computer then reads the data cards and compiles the desired information. The punch-out consists of a code which identifies the solvent, solute, and ligand, as well as the location of the data on the strip chart. An additional code, N, is provided in order to explain the computer decisions. RK and RPK represent the electrolyte specific resistance and the polarized specific resistance in kilohm-centimeters respectively, and P is the pressure in pounds per square inch absolute. Pressure readings (of secondary importance) have not been computed for certain portions of the data since appropriate formulas were not determined for computer use. The Tafel parameters C and D are punched along with the voltage X at the approximate figure of merit (W).

W is determined by letting X = 6.0 volts and then repeatedly letting X decrease in one-half volt steps down to 0.5 volts and computing Y for each of these voltage steps. When a maximum Y or W is determined, the computer prints out this result along with the corresponding X. It is not necessary to let X go down to 0.5 volts in order to calculate W. When W is found, the computer stops at this point. If Y does not peak within the limits X = 0.5 to 6.0 volts, the computer selects the highest value of Y and prints this as W along with the associated limit of X.

Negative values of W indicate that the particular electrolyte is probably unsuitable for batteries, while a very large W is an indication that the electrolyte may permit construction of high energy systems.

The output from the computer is received in the form of punched cards in order to conserve computer time. These cards are then displayed by means of a printer (IBM 407). This data may then be inspected for anomalies which become apparent in the course of computation. Data which requires further study or consideration is then deleted by removal of these cards from the deck. Table II, pages 28-48, was prepared from the first selected deck. The systems showing a W greater than 500 are of interest.

The code number identifies the solvent-solute-atmosphere and the particular scans selected from the recording. The last two digits of the code number, separated by a decimal point, indicate the general pressure level of the ligand atmosphere. The .01 constitutes a normal atmospheric reading of the given system, and it should be borne in mind that the solvents are utilized in the "as-received" condition, See Page 72.

The pressure chamber is purged with the ligand gas and sealed; additional ligand atmosphere is then gradually admitted over approximately 16 hours until the full vapor pressure of the ligand is approached. During this time, the pressure is gradually increasing; and readings are selected at electrochemical equilibrium conditions. The figures of merit, W, tabulated in Table II, pages 28-48, thereby indicate the performance of the system under an increasing ligand atmosphere pressure. The significance of this factor is quite obvious from an inspection of Table II where it may be seen that specific resistance and Tafel parameters vary considerably in reasonable trends. The following systems are selected as having considerable interest in that the values of W so reported exceed 500 watt hours per pound of net electrode reactants on the basis of equation (1) on page 7.

1) N, N-Dimethylformamide (DMF) + $AlCl_3$, KI + mild NH_3 atmosphere
2) as-received N, N-Dimethylformamide + NaI, KI
3) Pyridine + LiF + full NH_3 atmosphere
4) N-Methyl 2-Pyrrolidone + KSCN, KBr, $(CH_3)_4NI$ + CO_2 atmosphere
5) Acetonitrile + $(CH_3)_4NCl$ + mild NH_3 atmosphere
6) as-received Acetonitrile + LiCl
7) Dimethyl Sulfoxide + NaI, $NaCO_2CCl_3$ + SO_2 atmosphere
8) as-received Dimethyl Sulfoxide + $Al_2(SO_4)_3$, LiCl

Some of the systems above will be investigated further in order to account for non-linearity in the Tafel plots. These systems are the following:

Pyridine + LiF + full NH_3 atmosphere
N-Methyl 2-Pyrrolidone + KBr, $(CH_3)_4NI$ + CO_2 atmosphere
as-received Acetonitrile + LiCl
Acetontrile + $(CH_3)_4NCl$ + mild NH_3 atmosphere

Two sets of data are provided for the system N, N-Dimethylformamide + $AlCl_3$ + mild NH_3 atmosphere. The data in Part A of Tabel II, page 28, indicates that this system may yield high energies, while the data in Part B of Tabel II, page 35, indicates that the Tafel plots are extremely non-linear; and, hence, no W was computed. Notice also that the specific resistances in Part A are higher than those in Part B. It is suspected that the moisutre content and the degree of purity of the above systems cause the incongruity in the results.

SAMPLE EVALUATION OF SYSTEM NO. 1 ABOVE

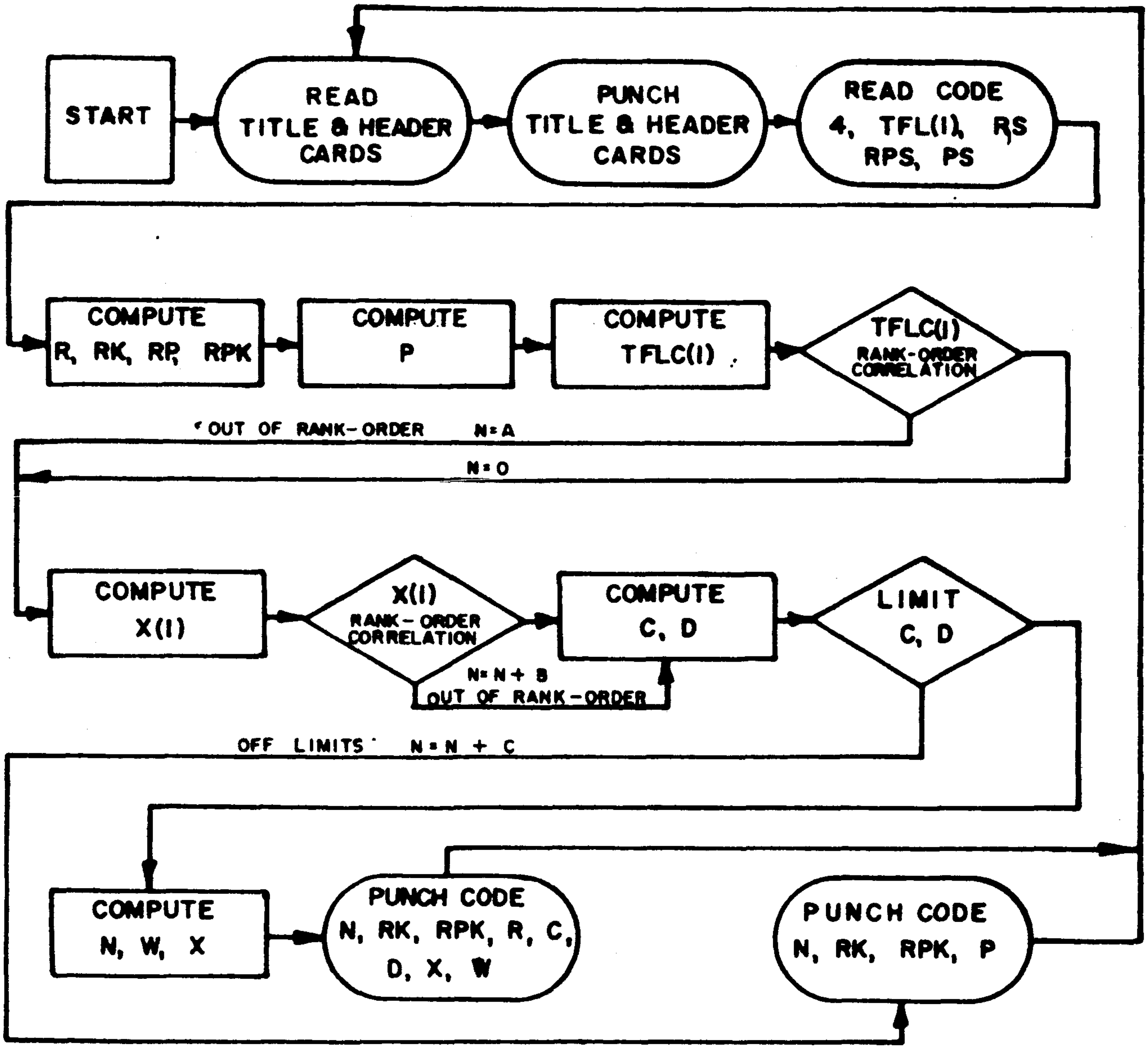
For the purpose of showing how Table II, A and B, provides the indication of utility in possible high energy density batteries, the data for the system N, N-Dimethylformamide + Aluminum Chloride + Ammonia atmosphere will be examined. On page 2 of Table II-A, the first results obtained for this system are shown. The code number identifies this system, RK is the specific resistance in kilohm-centimeters of the saturated to mildly concentrated solutions which result from the addition of Aluminum Chloride to N, N-Dimethylformamide under the effect of the gradually increasing atmosphere. Note that under code number .01 the atmosphere is a normal air atmosphere and no ligand has been supplied. At code number .02, the system has been flushed with the ligand (ammonia). The code numbers extend, in this case, to .18 during which the pressure is gradually increasing as the ammonia is added to the system via a capillary. Final equilibrium has been established at the highest code number. The value of C listed for this system shifts in a rational pattern over the full range of ammonia atmosphere pressures (from 0 absolute to about 125 pounds per square inch absolute). D also is observed to go through a number of transitions. Normally, we note that a decrease in C is accompanied by a decrease in D. However, an increase in C, and a corresponding decrease in D, is desirable. It would appear that the ratio of C over D, the exchange current of the corrosion reaction, is a major determinent of the quality of the electrolyte. Thus, in the example of N, N-Dimethylformamide - Ammonia - Aluminum Chloride on page A2, the reasonable value of specific resistance, combined with the favorable ratio of C over D, results in reasonably high values of X (the electrode potential) and high figures of merit for the system which are generally above 500 watt hours per pound. It is also to be noted that there are certain ranges of ligand pressure which will be most favorable for different purposes. The points of code numbers .01 and .02 have the merit of requiring no pressure in addition to one atmosphere, 592 watt hours per pound being for an air atmosphere and 641 being for an ammonia atmosphere of 14.7 pounds per square inch absolute. Occasionally, since the effect of liganation has much of a random character, we may expect a desirable set of systems to combine. For example, in comparing code numbers .03 and .04, it is to be noted that C is increasing—this is favorable. At the same time, D is decreasing—this is also favorable. Thus, the figure of merit has risen to 1468 watt hours per pound for the system at this particular partial pressure of ammonia. Other choice points are also available, such as code .11 where the figure of 3,000 watt hours per pound was exceeded through a severe drop in the value of D combined with only a modest decrease in the relative value of C. It is through the proper, and admittedly involved, balance of these factors whereby we are able to consider the merit of one solvent against another via the automatic computing process. For the code .11, note that RPK is essentially higher than RK. We believe this is an index of a film type inhibitation of solvent type decomposition. Such experience as we have to date seems to indicate that the film forming character—while it inhibits the decomposition of the solvent—does not appear to preclude proper electrode function.

This system also provides an opportunity to compare subsequent data readings. In this case, there is anomaly to be resolved which may make this example of future value. On page B1 the system N, N-Dimethylformamide - Aluminum Chloride - Ammonia appears again under the same code number. This data was collected at a later date using the same materials after a storage period of approximately two months. Comparison of RK determined at these two different times show that the resistance of the second combination is substantially less. Since the Aluminum Chloride was freshly dessicated for the first run, we preseume that this hydroscopic material has collected water during the two month's storage period.

In Table II-B, we now have the added advantage of a three-digit decision record code listed as N. This record code refers to the decision points in the program shown in Figure V, page 25. The diamond-shaped boxes symbolize the decisions made by the computer in evaluating the data. Note that the TFLC (I) or Tafel current rank order correlation decision determines sequentially if the Tafel current I(9) in Figure VI, page 26, is greater than I(8); then if I(8) is greater than I(7), and if I(7) is greater than I(6). If I(9) were greater than I(8), the value of N would be increased by 100. If I(8) is greater than I(7), N would be increased by 200; and if I(7) is greater than I(6), N would be increased by 400. Going now to the rank order correlation of the voltage X, the tens digit is similarily treated, that is, if the Tafel voltage should regress, then the code 10, 20, 40 or combination thereof is added to N. Finally, after the values of C and D have been computed, a lower limit is placed upon the value of D. If D is less than +.01, the figure which is added to N is 1. The upper limit of D is 99, and if exceeded, results in the addition of 2 to N. There is an upper limit on C of 999 and exceeding of this upper limit results in an addition of three to N. W is not computed in this program given on page 27when the units digit of N is other than 0. Thus, on page B1, for N, N-Dimethylformamide - Ammonia - Aluminum Chloride, after the materials were stored on the shelf, the code 61 indicates that the Tafel line was retrograde; and D was negative. Hence, no characterization of the Tafel data was practical and no figure of W could be computed. In viewing the data of Table II-A and II-B together, it is inferred that the system under consideration has great merit, but that care will have to be exercised to insure freedom from impurity.

Fig. V

COMPUTER FLOW CHART



LEGEND:

CODE = CARD IDENTIFICATION
I = TAFEL CURRENT SUBSCRIPTS
TFL(I) = TAFEL CURRENT READING
TFLC(I) = TAFEL CURRENT (AMPERES)
RS = CELL RESISTANCE READING
R = CELL SPECIFIC RESISTANCE (ohm-cm)
RK = CELL SPECIFIC RESISTANCE (K ohm-cm)
RPS = POLARIZED CELL RESISTANCE READING
RP = POLARIZED CELL SPECIFIC RESISTANCE (ohm-cm)
RPK = POLARIZED CELL SPECIFIC RESISTANCE (K ohm-cm)
PS = PRESSURE READING
P = PRESSURE (psi abs.)
X(I) = INTERFACIAL VOLTAGE
C, D = MODIFIED TAFEL CONSTANTS
W = MAXIMUM Y (watt hrs/ lb)
X = VOLTAGE AT W
N = COMPUTER DECISION CODE
A, B, & C = COMPONENTS OF N

CODE		I(6)	I(7)	I(8)	I(9)	R	ρ
10001A	1	226	194	142	94	86	75
10001A	2	236	202	150	98	86	88
10001A	3	226	204	149	98	99	88
10001A	4	229	204	150	99	110	65
10001A	5	209	183	139	93	110	55
10001A	6	127	96	70	51	130	63
10001A	7	110	78	50	36	140	55
10001A	8	130	101	71	50	140	48
10001A	9	161	136	104	76	130	48
10001A	10	197	173	131	100	110	48
10001A	11	218	195	154	118	100	80
10001A	12	220	198	156	118	95	88
10001A	13	218	196	155	116	95	88

FIGURE VI
DATA SHEET

```
C   LIVINGSTON ELECTRONIC CORP.   PROGRAM   NO. 3
   40 READ 42
      PUNCH 42
      READ 43
      PUNCH 43
      PUNCH 44
      PUNCH 41
    1 READ 2,CODE,TFL6,TFL7,TFL8,TFL9,RS,RPS,PS
      IF(CODE)45,46,45
   45 P=0.97*(PS-130.0)
      N=0
      IF(RS-60.0)50,50,51
   50 RK=EXPF(3.94-0.026*RS)
      GO TO 54
   51 IF(RS-410.0)52,52,53
   52 RK=EXPF(2.87-0.0086*RS)
      GO TO 54
   53 RK=EXPF(7.48-0.0198*RS)
   54 R=1000.*RK
      IF(RPS-60.0)55,55,56
   55 RPK=EXPF(3.94-0.026*RPS)
      GO TO 59
   56 IF(RPS-410.0)57,57,58
   57 RPK=EXPF(2.87-0.0086*RPS)
      GO TO 59
   58 RPK=EXPF(7.48-0.0198*RPS)
   59 RP= 1000. *RPK
      TFLC9=2.E-6*TFL9
      TFLC8=1.E-6*TFL8
      TFLC7=4.E-7*TFL7
      TFLC6=2.E-7*TFL6
      IF(TFLC9-TFLC8)9,9,3
    3 IF(TFLC8-TFLC7)8,8,4
    4 IF(TFLC7-TFLC6)7,7,5
    9 N=N+400
      GO TO 3
    8 N=N+200
      GO TO 4
    7 N=N+100
      GO TO 5
   10 PUNCH 11,CODE,N,RK,RPK,P
      GO TO 1
    5 X9=10.-(0.02*500.*TFL9/RS)
      X8=10.-(0.01*(500.+RS)/RS*TFL8)
      X7=10.-(0.004*(500.+4.0*RS)/RS*TFL7)
      X6=10.-(0.002*(500.+9.0*RS)/RS*TFL6)
      IF(X9-X8)19,19,12
   12 IF(X8-X7)18,18,13
   13 IF(X7-X6)17,17,20
   19 N=N+40
      GO TO 12
   18 N=N+20
```

```
      GO TO 13
   17 N=N+10
      GO TO 20
   20 D=(X9+X8-X7-X6)/LOG(TFLC9*TFLC8/(TFLC7*TFLC6))
      IF(D-0.01)21,21,22
   21 N=N+1
      GO TO 10
   22 IF(D-99.0)24,24,23
   23 N=N+2
      GO TO 10
 24 C=.25*((X9+X8+X7+X6)-D*(4.63+LOG(TFLC9*TFLC8*TFLC7*TFLC6)))
      IF(C-999.0)26,25,25
   25 N=N+3
      GO TO 10
   26 X=6.0
   27 W=3261.0*(1.0-0.37*SQRTF(R)*EXPF((6.0-C)/(2.0*D)))
   28 X=X-0.5
      Y=(49.6*X*EXP(0.4*X))*(1.0-0.9*SQRT(R/X)*EXP((X-C)/(2.*D)))
      IF(Y-W)30,30,32
   30 X=X+0.5
   31 PUNCH 34,CODE,N,RK,RPK,P,C,D,X,W
      GO TO 1
   32 W=Y
      IF(X-0.5)31,31,28
   46 PUNCH 44
      PUNCH 44
      GO TO 40
    2 FORMAT(F9.2,F5.0,F5.0,F5.0,F5.0,F5.0,F5.0,F5.0)
   11 FORMAT(F9.2,I4,F6.2,F6.2,F6.1)
   34 FORMAT(F9.2,I4,F6.2,F6.2,F6.1,F7.2,F7.2,F5.1,F7.0)
 41FORMAT(49H   CODE        N   RK     RPK      P       C       D      X,6X,1HW)
 42FORMAT(15X,49H FIRST TITLE CARD                                    )
 43FORMAT(15X,49H SECOND TITLE CARD                                   )
 44FORMAT(1H )
      END
```

TABLE II - A

LEGEND

The electrolyte specific resistance RK and the polarized specific resistance RPK are limited to 4,990 kilohm-centimeters at full scale deflection of the recorder.

The pressure (P) has been omitted for want of an appropriate formula for computer evaluation.

N indicates whether or not the modified Tafel constants C and D are within set limits. N = 0 means that C and D are within limits, while N = 3 indicates that C and D are out of limits. No check for linearity of the Tafel plots is provided.

N,N-DIMETHYLFORMAMIDE/AMMONIA
SODIUM BROMIDE

CODE	N	RK	RPK	C	D	X	W
14110.01	0	1.16	1.16	2.20	.07	1.5	103.
14110.02	0	.98	.98	2.75	.14	1.5	92.
14110.03	0	.94	.96	2.76	.18	1.0	58.
14110.04	0	.96	.96	2.70	.17	1.0	58.
14110.05	0	.94	4.00	3.25	.24	1.5	55.

N,N-DIMETHYLFORMAMIDE/AMMONIA
SODIUM IODIDE

CODE	N	RK	RPK	C	D	X	W
14111.01	0	1.65	2.01	13.39	.96	6.0	2188.
14111.02	0	1.52	1.96	13.33	1.04	6.0	1855.
14111.03	0	1.46	2.04	16.29	1.51	6.0	1702.
14111.04	0	1.57	2.25	15.69	1.50	6.0	1369.
14111.05	0	1.41	2.19	14.28	1.34	6.0	1169.
14111.06	0	1.16	2.07	14.03	1.37	6.0	1047.

N,N-DIMETHYLFORMAMIDE/AMMONIA
POTASSIUM BROMIDE

CODE	N	RK	RPK	C	D	X	W
14106.01	0	.37	.37	6.05	.59	2.5	152.
14106.02	0	.28	.28	9.10	1.12	3.5	231.
14106.03	0	.28	.26	9.00	1.08	3.5	250.
14106.04	0	.26	.26	9.33	1.11	4.0	321.
14106.05	0	.20	.20	9.31	1.11	4.5	413.
14106.06	0	.20	.24	9.46	1.14	4.5	407.

N,N-DIMETHYLFORMAMIDE/AMMONIA
MAGNESIUM SULPHATE

CODE	N	RK	RPK	C	D	X	W
14120.01	0	.20	.22	2.70	.21	1.0	57.
14120.02	0	.16	.14	5.02	.65	1.5	50.
14120.03	0	.10	.12	5.64	.73	2.5	112.
14120.04	0	.14	.14	5.36	.69	2.0	71.
14120.05	0	.08	.06	5.87	.76	2.5	149.
14120.06	0	.10	.10	5.42	.70	2.0	97.

N,N-DIMETHYLFORMAMIDE/AMMONIA
TETRAMETHYL AMMONIUM CHLORIDE 162
163

CODE	N	RK	RPK	C	D	X	W	
								164
14113.01	0	20.30	28.46	12.03	1.17	.5	-9.	165
14113.02	0	19.06	27.87	14.24	1.45	.5	-16.	166
14113.03	0	18.57	25.71	12.68	1.24	.5	-9.	167
14113.04	0	13.92	22.25	12.72	1.21	1.5	17.	168
14113.05	0	7.60	10.40	7.52	.59	2.0	106.	169
14113.06	0	6.39	10.49	11.71	1.15	2.0	50.	170
14113.07	0	6.44	11.55	11.21	1.08	2.5	63.	171
14113.08	0	6.61	11.73	10.08	.92	2.5	74.	172
14113.09	0	6.23	11.64	6.97	.77	2.5	100.	173
14113.10	0	5.47	10.32	8.91	.78	2.5	104.	174
14113.11	3	5.15	9.53					175
14113.12	0	5.15	9.23	8.23	.70	2.0	97.	176
14113.13	0	4.53	8.18	8.22	.71	2.5	101.	177
14113.14	0	4.32	7.36	8.20	.73	2.0	88.	178
14113.15	0	4.20	6.77	7.70	.68	2.0	78.	179
14113.16	0	4.20	7.18	8.13	.75	2.0	67.	180
14113.17	0	4.00	6.94	8.30	.76	2.0	73.	181
14113.18	0	4.12	7.00	8.19	.74	2.0	78.	182

N,N-DIMETHYLFORMAMIDE/AMMONIA
ALUMINUM CHLORIDE 013
14

CODE	N	RK	RPK	C	D	X	W	
								015
14102.01	0	5.29	10.24	14.36	1.24	5.0	592.	016
14102.02	0	5.52	9.68	8.54	.49	4.0	641.	017
14102.03	0	6.23	11.36	9.22	.49	5.0	1040.	018
14102.04	0	7.46	12.52	9.50	.45	5.5	1468.	019
14102.05	0	8.79	15.00	12.28	.77	5.5	1343.	020
14102.06	0	8.31	17.47	13.45	.95	5.5	1150.	021
14102.07	0	8.24	17.77	12.95	.92	5.5	972.	022
14102.08	0	9.01	16.40	12.07	.81	5.0	926.	023
14102.09	0	10.66	19.76	13.18	.60	4.5	805.	024
14102.10	0	10.83	8.05	20.68	1.95	5.5	452.	025
14102.11	0	13.14	18.73	10.15	.30	6.0	3101.	026
14102.12	0	13.92	19.23	14.26	.69	6.0	2892.	027
14102.13	0	13.92	16.57	10.92	.40	6.0	2938.	028
14102.14	0	12.93	16.86	7.12	.07	6.0	3204.	029
14102.15	0	10.83	13.25	7.26	.17	5.5	1762.	030
14102.16	0	9.68	13.69	6.22	.11	5.0	1556.	031
14102.17	0	9.06	14.03	6.74	.17	5.0	1376.	032
14102.18	0	9.05	14.63	7.02	.19	5.0	1401.	033

ACETONITRILE/AMMONIA
LITHIUM CHLORIDE

CODE	N	RK	RPK	C	D	X	W
13105.01	0	.70	1.46	19.75	2.57	6.0	1048.
13105.02	0	.72	1.46	18.55	2.41	6.0	828.
13105.03	0	.84	1.57	17.88	2.33	5.5	526.
13105.04	0	.63	1.03	17.34	2.25	6.0	782.
13105.05	0	.66	1.11	12.82	1.67	4.0	167.
13105.06	3	.70	1.03				
13105.07	0	.18	.61	6.52	.84	2.5	95.
13105.08	0	.02	.22	7.07	.91	5.0	769.
13105.09	0	.12	.08	6.79	.88	3.0	165.
13105.10	0	.02	.08	3.47	.44	2.0	99.

ACETONITRILE/AMMONIA
POTASSIUM BROMIDE

CODE	N	RK	RPK	C	D	X	W
13106.01	3	11.55	11.92				
13106.02	3	12.32	12.72				
13106.03	3	17.62	14.87				
13106.04	3	22.05	16.04				
13106.05	3	30.32	22.46				
13106.06	3	8.05	12.52				
13106.07	3	3.81	2.91				
13106.08	3	4.70	4.57				
13106.09	3	6.77	7.36				
13106.10	0	16.45	17.47	1.18	.47	.5	-2355.

ACETONITRILE/AMMONIA
MAGNESIUM SULPHATE

CODE	N	RK	RPK	C	D	X	W
13120.01	0	.52	.52	6.63	.67	2.5	127.
13120.02	0	.52	.46	6.85	.69	2.5	144.
13120.03	0	.63	.61	6.83	.69	2.5	122.
13120.04	0	.70	.66	6.06	.56	2.0	117.
13120.05	0	.54	.59	5.65	.49	2.5	153.
13120.06	0	.35	.22	5.86	.53	2.5	186.
13120.07	0	.52	.39	2.48	.33	.5	-13.
13120.08	0	.20	.20	7.60	.96	3.0	156.
13120.09	0	.20	.26	7.17	.89	3.0	136.
13120.10	0	.26	.35	8.09	1.05	3.0	121.

PYRIDINE/AMMONIA
LITHIUM FLUORIDE

CODE	N	RK	RPK	C	D	X	W
10704.01	0	76.20	90.00	5.64	.44	.5	-3.
10704.02	0	64.62	71.96	15.55	1.48	.5	-31.
10704.03	3	156.66	92.04				
10704.04	0	70.64	86.15	16.87	1.52	.5	-18.
10704.05	0	45.55	58.49	21.10	2.09	.5	-30.
10704.06	0	55.78	69.36	16.18	1.47	.5	-14.
10704.07	0	17.17	59.44	33.77	3.25	6.0	1041.

2 ETHANOL PYRIDINE/AMMONIA
ALUMINUM FLUORIDE

CODE	N	RK	RPK	C	D	X	W
11701.01	3	54.10	53.29				
11701.02	3	58.49	58.49				
11701.03	3	68.12	68.12				
11701.04	3	70.64	70.64				
11701.05	3	70.64	73.33				
11701.06	3	49.52	56.66				
11701.07	3	39.50	39.01				
11701.08	3	9.92	10.00				
11701.09	3	23.33	23.78				

2 ETHANOL PYRIDINE/AMMONIA
ALUMINUM CHLORIDE

CODE	N	RK	RPK	C	D	X	W
11702.01	0	5.82	6.23	4.06	.26	1.5	74.
11702.02	0	5.52	5.62	1.89	.01	1.5	135.
11702.03	3	6.02	6.12				
11702.04	3	6.12	6.23				
11702.05	3	6.33	6.50				
11702.06	3	6.33	6.55				
11702.07	0	5.67	5.97	2.00	.02	1.5	135.
11702.08	3	6.89	7.24				
11702.09	0	3.66	4.28	2.84	.12	1.5	109.

2 ETHANOL PYRIDINE/AMMONIA
LITHIUM FLUORIDE

CODE	N	RK	RPK	C	D	X	W
11704.01	3	28.16	28.46				
11704.02	3	36.29	37.61				
11704.03	3	40.50	41.02				
11704.04	3	41.54	42.08				
11704.05	3	43.76	43.76				
11704.06	3	42.63	42.63				
11704.07	3	36.72	38.07				
11704.08	3	40.00	42.08				
11704.09	3	24.01	27.31				

2 ETHANOL PYRIDINE/AMMONIA
LITHIUM CHLORIDE

CODE	N	RK	RPK	C	D	X	W
11705.01	3	38.54	38.54				
11705.02	3	30.98	32.37				
11705.03	0	12.62	14.87	3.65	.15	2.0	151.
11705.04	0	7.85	10.40	4.99	.31	2.0	115.
11705.05	0	5.72	7.24	4.57	.26	2.0	132.
11705.06	3	10.66	6.02				
11705.07	0	4.08	5.33	4.20	.22	2.0	151.
11705.08	0	3.51	4.83	4.71	.29	2.0	141.
11705.09	0	7.85	8.93	3.20	.11	2.0	155.

2 ETHANOL PYRIDINE/AMMONIA
POTASSIUM BROMIDE

CODE	N	RK	RPK	C	D	X	W
11706.01	0	15.64	15.77	3.27	.16	1.5	84.
11706.02	0	16.73	17.17	2.39	.05	1.5	131.
11706.03	3	18.73	19.06				
11706.04	3	19.41	19.76				
11706.05	3	19.94	20.30				
11706.06	3	19.06	19.06				
11706.07	3	15.00	15.00				
11706.08	3	13.69	13.04				
11706.09	0	4.70	5.62	3.69	.14	2.0	198.

2 ETHANOL PYRIDINE/AMMONIA
TETRAMETHYL AMMONIUM CHLORIDE

CODE	N	RK	RPK	C	D	X	W
11713.01	0	406.66	406.66				
ERROR F8	.87108423E+03						
					90.71	.5	-172.
11713.02	3	86.15	86.15				
11713.03	3	66.92	66.92				
11713.04	3	58.49	57.56				
11713.05	3	50.97	50.97				
11713.06	3	49.52	48.13				
11713.07	3	43.19	42.63				
11713.08	3	41.02	41.02				
11713.09	0	17.47	17.47	3.80	.14	2.0	188.

ACETONITRILE/AMMONIA
ALUMINUM CHLORIDE

CODE	N	RK	RPK	C	D	X	W
13102.01	0	.02	.02	1.67	.05	1.0	73.
13102.02	0	.02	.02	1.79	.06	1.5	83.
13102.03	0	.02	.02	1.90	.08	1.5	98.
13102.04	0	.10	.10	1.80	.06	1.0	72.
13102.05	0	.06	.16	1.90	.06	1.5	94.
13102.06	0	.08	.14	2.03	.08	1.5	94.
13102.07	0	.20	.28	3.74	.36	1.5	69.
13102.08	0	1.31	1.33	1.85	.08	1.0	58.
13102.09	0	1.26	1.26	1.48	.03	1.0	73.
13102.10	3	14.63	15.77				

ACETONITRILE/AMMONIA
ALUMINUM SULPHATE

CODE	N	RK	RPK	C	D	X	W
13103.01	0	1.31	2.37	8.05	1.06	.5	-10.
13103.02	0	1.57	2.50	5.65	.76	.5	-21.
13103.03	0	1.57	2.59	9.15	1.21	.5	-13.
13103.04	0	1.23	1.28	7.39	.96	.5	-10.
13103.05	0	1.01	1.01	8.06	1.06	1.0	-2.
13103.06	0	1.38	2.85	.32	.06	.5	-5120.
13103.07	0	1.28	2.10	.15	.04	.5	-82454.
13103.08	0	.82	.86	5.74	.75	.5	-4.
13103.09	0	.86	.79	5.29	.70	.5	-6.
13103.10	0	.75	[illegible]	4.45	[illegible]	.5	-6.

TABLE II - B

LEGEND

The electrolyte specific resistance RK and the polarized specific resistance RPK are limited to 51.41 kilohm-centimeters. Any values of RK and RPK at full scale deflection of the recorder at this point should be interpreted to mean that the actual specific resistance is higher than this value.

The pressure (P) has been omitted in certain areas because of mechnaical difficulties with the pressure transducer.

A pressure of 358.9 pounds per square inch absolute means that the recorder reads off-scale and that the actual pressure is higher than this value.

N indicates linearity of the Tafel plots and whether or not the modified Tafel constants C and D are within set limits. N = 0 when all conditions for linearity are met.

This table, II - B, is a direct reproduction of the computer punchout using the Fortran program on pages 27 and 27a.

N,N-DIMETHYLFORMAMIDE/AMMONIA
ALUMINUM FLUORIDE

CODE	N	RK	RPK	P	C	D	X	W
14101.01	71	3.21	2.70	12.6				
14101.02	71	3.98	3.15	40.7				
14101.03	71	32.20	34.81	31.0				
14101.04	71	29.78	28.27	64.9				
14101.05	71	21.24	22.37	90.2				
14101.06	71	19.64	20.16	90.2				
14101.07	71	15.95	16.37	87.3				
14101.08	71	14.01	14.01	87.3				

N,N-DIMETHYLFORMAMIDE/AMMONIA
ALUMINUM CHLORIDE

CODE	N	RK	RPK	P	C	D	X	W
14102.01	61	1.56	2.05	14.5				
14102.03	61	1.40	2.05	53.3				
14102.04	61	1.25	1.96	69.8				
14102.05	71	1.58	1.65	89.2				
14102.06	61	1.45	1.49	90.2				
14102.07	61	1.13	1.14	89.2				
14102.08	61	.89	.93	87.3				

N,N-DIMETHYLFORMAMIDE/AMMONIA
ALUMINUM SULPHATE

CODE	N	RK	RPK	P	C	D	X	W
14103.01	71	5.06	5.66	14.5				
14103.02	71	4.26	4.49	42.6				
14103.03	71	4.30	4.53	53.3				
14103.04	71	4.12	4.34	67.9				
14103.05	71	6.96	7.59	87.3				
14103.06	71	7.92	8.86	86.3				
14103.07	71	7.85	8.94	89.2				
14103.08	71	8.06	8.86	87.3				

N,N-DIMETHYLFORMAMIDE/AMMONIA
LITHIUM FLUORIDE

CODE	N	RK	RPK	P	C	D	X	W
14104.01	71	48.81	46.33	14.5				
14104.02	71	37.63	37.63	42.6				
14104.03	71	30.56	30.56	52.3				
14104.04	71	18.17	19.14	65.9				
14104.05	71	20.69	26.84	87.3				
14104.06	71	21.24	24.82	86.3				
14104.07	71	18.65	21.80	89.2				
14104.08	71	22.96	19.64	89.2				

N,N-DIMETHYLFORMAMIDE/AMMONIA
LITHIUM CHLORIDE

CODE	N	RK	RPK	P	C	D	X	W
14105.01	30	.34	.45		4.12	.27	2.0	167.
14105.02	20	.25	.42		4.94	.37	2.5	217.
14105.03	20	.27	.44		4.83	.36	2.5	204.
14105.04	61	.23	.30					
14105.05	40	.26	.28		3.22	.31	1.0	42.
14105.06	61	.32	.35					
14105.07	61	.30	.35					
14105.08	61	.34	.37					
14105.09	61	.34	.38					

N,N-DIMETHYLFORMAMIDE/AMMONIA
POTASSIUM IODIDE

CODE	N	RK	RPK	P	C	D	X	W
14107.01	400	.16	19.14		304.13	36.73	6.0	2991.
14107.02	400	.20	17.25		223.38	26.71	6.0	2959.
14107.03	400	.28	16.37		238.35	28.02	6.0	2941.
14107.04	400	.14	14.01		112.54	13.64	6.0	2967.
14107.05	0	.10	6.23		12.65	1.40	6.0	2106.
14107.06	0	.10	7.59		22.53	2.74	6.0	2643.
14107.07	0	.10	8.49		26.91	3.29	6.0	2741.
14107.08	400	.12	8.56		34.41	4.24	6.0	2785.
14107.09	40	.10	7.46		3.72	.33	2.0	107.

N,N-DIMETHYLFORMAMIDE/AMMONIA
NO SOLUTE

CODE	N	RK	RPK	P	C	D	X	W
14100.01	71	50.09	50.09					
14100.02	72	51.41	51.41					
14100.03	72	51.41	51.41					
14100.04	71	47.56	41.76					
14100.05	71	26.84	23.57					
14100.06	71	20.16	17.70					
14100.07	71	9.91	9.33					

ACETONITRILE/AMMONIA
NO SOLUTE

CODE	N	RK	RPK	P	C	D	X	W
13100.01	71	32.20	41.76					
13100.02	71	38.62	47.56					
13100.03	71	38.62	48.81					
13100.04	71	29.78	41.76					
13100.05	71	29.02	42.86					
13100.06	71	29.78	41.76					
13100.07	71	25.48	39.64					

ACETONITRILE/AMMONIA
ALUMINUM FLUORIDE

CODE	N	RK	RPK	P	C	D	X	W
13101.01	71	30.56	39.64					
13101.02	71	39.64	45.15					
13101.03	71	33.04	45.15					
13101.04	71	15.95	29.78					
13101.05	71	14.76	2.79					
13101.06	51	6.28	9.01					
13101.07	71	6.28	9.01					

ACETONITRILE/AMMONIA
LITHIUM FLUORIDE

CODE	N	RK	RPK	P	C	D	X	W
13104.01	71	37.63	45.15					
13104.02	71	41.76	50.09					
13104.03	71	45.15	50.09					
13104.04	71	28.27	46.33					
13104.05	71	18.17	39.64					
13104.06	71	17.25	37.63					
13104.07	71	15.14	33.04					

ACETONITRILE/AMMONIA
TETRAMETHYL AMMONIUM CHLORIDE

CODE	N	RK	RPK	P	C	D	X	W
13113.01	41	.53	.56					
13113.02	40	.47	.60		2.15	.13	1.0	52.
13113.03	0	.56	14.01		28.06	3.33	6.0	2219.
13113.04	420	.45	22.96		15.83	1.78	6.0	1610.
13113.05	21	.37	.43					
13113.06	61	.32	.45					
13113.07	61	.39	.43					

PYRIDINE/AMMONIA
CLORANIL

CODE	N	RK	RPK	P	C	D	X	W
10724.01	71	10.80	10.80	14.5				
10724.02	61	11.68	11.98	38.8				
10724.03	71	16.37	16.37	44.6				
10724.04	71	50.09	50.09	48.5				
10724.05	71	50.09	50.09	48.5				
10724.06	72	51.41	51.41	74.6				
10724.07	72	51.41	51.41	68.8				

PYRIDINE/AMMONIA
NO SOLUTE

CODE	N	RK	RPK	P	C	D	X	W
10700.01	472	51.41	51.41	13.5				
10700.02	771	51.41	51.41	38.8				
10700.03	771	51.41	51.41	42.6				
10700.04	771	51.41	51.41	51.4				
10700.05	671	51.41	51.41	45.5				
10700.06	72	51.41	51.41	75.6				
10700.07	472	51.41	51.41	68.8				

PYRIDINE/AMMONIA
ALUMINUM CHLORIDE

CODE	N	RK	RPK	P	C	D	X	W
10702.01	71	5.71	3.59	14.5				
10702.02	71	3.38	3.36	38.8				
10702.03	71	3.65	3.56	42.6				
10702.04	71	4.12	4.12	48.5				
10702.05	71	4.37	4.37	48.5				
10702.06	71	4.41	4.41	77.6				
10702.07	71	4.12	4.19	67.9				

PYRIDINE/AMMONIA
LITHIUM CHLORIDE

CODE	N	RK	RPK	P	C	D	X	W
10705.01	71	4.89	4.85	12.8				
10705.02	71	4.55	4.50	37.8				
10705.03	71	5.29	4.69	42.6				
10705.04	71	5.71	4.89	48.5				
10705.05	71	6.23	5.33	47.5				
10705.06	71	5.17	5.06	77.6				
10705.07	71	6.01	4.77	67.9				

PYRIDINE/AMMONIA
POTASSIUM BROMIDE

CODE	N	RK	RPK	P	C	D	X	W
10706.01	472	51.41	51.41	14.5				
10706.02	472	51.41	51.41	38.8				
10706.03	472	51.41	51.41	42.6				
10706.04	472	51.41	51.41	48.5				
10706.05	472	51.41	51.41	48.5				
10706.06	472	51.41	51.41	77.6				
10706.07	472	51.41	51.41	67.9				

PYRIDINE/AMMONIA
TETRAMETHYL AMMONIUM CHLORIDE

CODE	N	RK	RPK	P	C	D	X	W
10713.01	72	51.41	51.41	13.5				
10713.02	72	51.41	51.41	38.8				
10713.03	72	51.41	51.41	52.3				
10713.04	71	50.09	50.09	48.5				
10713.05	71	50.09	50.09	45.5				
10713.06	71	48.81	45.15	75.6				
10713.07	72	51.41	50.09	68.8				

PYRIDINE/AMMONIA
TETRAMETHYL AMMONIUM IODIDE

CODE	N	RK	RPK	P	C	D	X	W
10714.01	71	50.09	50.09	14.5				
10714.02	72	51.41	51.41	35.8				
10714.03	72	51.41	51.41	44.6				
10714.04	71	50.09	50.09	46.5				
10714.05	71	48.81	50.09	48.5				
10714.06	71	47.56	50.09	74.6				
10714.07	72	51.41	51.41	68.8				

PYRIDINE/AMMONIA
TRIMETHYLAMINE HYDROCHLORIDE

CODE	N	RK	RPK	P	C	D	X	W
10716.01	71	36.67	36.67	12.6				
10716.02	71	40.69	39.64	35.8				
10716.03	71	41.76	39.64	42.6				
10716.04	71	50.09	50.09	48.5				
10716.05	71	50.09	47.56	46.5				
10716.06	71	45.15	45.15	73.7				
10716.07	71	33.04	33.04	69.8				

N-METHYL 2-PYRROLIDONE/CARBON DIOXIDE
ALUMINUM SULPHATE

CODE	N	RK	RPK	P	C	D	X	W
32303.01	71	34.81	38.62					
32303.02	71	20.16	23.57					
32303.03	71	12.62	13.65					
32303.04	71	9.41	9.74					
32303.05	71	8.13	8.13					
32303.06	71	7.14	7.14					
32303.07	71	6.61	6.61					

N-METHYL 2-PYRROLIDONE/CARBON DIOXIDE
LITHIUM FLUORIDE

CODE	N	RK	RPK	P	C	D	X	W
32304.01	61	.47	.47					
32304.02	71	1.22	1.22					
32304.03	71	1.26	1.25					
32304.04	71	1.35	1.26					
32304.05	71	1.31	1.23					
32304.06	71	1.35	2.97					
32304.07	71	1.20	1.05					
32304.08	71	1.10	.93					

N-METHYL 2-PYRROLIDONE/CARBON DIOXIDE
LITHIUM CHLORIDE

CODE	N	RK	RPK	P	C	D	X	W
32305.01	71	7.27	8.34					
32305.02	61	1.88	1.74					
32305.03	71	1.79	1.83					
32305.04	71	1.74	1.74					
32305.05	71	1.82	1.75					
32305.06	71	2.20	1.88					
32305.07	71	2.35	2.21					
32305.08	71	2.68	3.59					

N-METHYL 2-PYRROLIDONE/CARBON DIOXIDE
POTASSIUM BROMIDE

CODE	N	RK	RPK	P	C	D	X	W
32306.01	71	3.29	6.50	13.5				
32306.02	71	2.79	6.56	16.4				
32306.03	400	3.10	11.08	77.6	274.67	30.45	6.0	2444.
32306.04	701	3.56	12.30	84.3				
32306.05	701	3.62	11.98	87.3				
32306.06	341	3.50	13.65	82.4				
32306.07	701	3.29	14.01	84.3				
32306.08	701	3.38	14.76	83.4				
32306.09	701	3.44	15.14	82.4				
32306.10	701	3.38	15.54	80.5				
32306.11	501	3.21	14.38	84.3				
32306.12	701	3.10	15.14	141.6				

N-METHYL 2-PYRROLIDONE/CARBON DIOXIDE
NO SOLUTE

CODE	N	RK	RPK	P	C	D	X	W
32300.01	71	.81	.79	14.5				
32300.02	71	.91	.88	38.8				
32300.03	71	.81	.83	170.7				
32300.04	61	.86	.87	358.9				
32300.05	61	.86	.89	358.9				
32300.06	61	.81	.81	358.9				
32300.07	61	.77	.80	358.9				
32300.08	61	.83	.83	358.9				
32300.09	61	.79	.81	358.9				
32300.10	61	.89	.90	358.9				
32300.11	61	.81	.83	358.9				
32300.12	61	.81	1.93	358.9				
32300.13	61	.86	.82	358.9				
32300.14	61	.81	.83	358.9				
32300.15	61	.84	.86	358.9				
32300.16	61	.88	.90	358.9				

N-METHYL 2-PYRROLIDONE/CARBON DIOXIDE
ALUMINUM FLUORIDE

CODE	N	RK	RPK	P	C	D	X	W
32301.01	71	27.54	35.73					
32301.02	71	29.02	33.04					
32301.03	71	29.02	33.91					
32301.04	71	30.56	35.73					
32301.05	71	29.78	34.81					
32301.06	71	30.56	34.81					
32301.07	71	29.02	31.37					
32301.08	71	28.27	29.78					

N-METHYL 2-PYRROLIDONE/CARBON DIOXIDE
ALUMINUM CHLORIDE

CODE	N	RK	RPK	P	C	D	X	W
32302.01	61	.45	.49					
32302.02	71	1.40	1.39					
32302.03	71	1.86	1.93					
32302.04	61	2.14	2.07					
32302.05	61	2.31	2.37					
32302.06	61	2.56	2.54					
32302.07	61	2.52	2.61					
32302.08	61	2.35	2.44					

N-METHYL 2-PYRROLIDONE/CARBON DIOXIDE
POTASSIUM IODIDE

CODE	N	RK	RPK	P	C	D	X	W
32307.01	61	.14	.17	13.5				
32307.02	21	.13	.99	16.4				
32307.03	601	.14	10.08	79.5				
32307.04	701	.16	12.96	85.3				
32307.05	701	.16	14.01	87.3				
32307.06	701	.21	15.95	83.4				
32307.07	701	.29	17.70	84.3				
32307.08	701	.41	18.17	83.4				
32307.09	701	.46	18.65	84.3				
32307.10	701	.55	20.16	79.5				
32307.11	701	.57	19.14	82.4				
32307.12	701	.57	19.14	163.9				

N-METHYL 2-PYRROLIDONE/CARBON DIOXIDE
POTASSIUM THIOCYANATE

CODE	N	RK	RPK	P	C	D	X	W
32309.01	21	.15	.26	14.5				
32309.02	21	.17	1.48	19.4				
32309.03	21	.19	1.45	80.5				
32309.04	21	.21	1.86	85.3				
32309.05	20	.21	2.12	87.3	2.35	.06	1.5	133.
32309.06	0	.29	5.61	81.4	22.12	2.46	6.0	2476.
32309.07	0	.94	5.91	84.3	15.24	1.53	6.0	1441.
32309.08	0	1.77	6.28	84.3	13.20	1.30	4.5	487.
32309.09	40	2.12	6.07	79.5	10.29	.94	3.5	280.
32309.10	61	7.59	2.84					
32309.11	0	2.14	5.36	82.4	28.05	3.02	6.0	1795.
32309.12	0	.74	6.56	162.9	16.15	1.62	6.0	1605.

N-METHYL 2-PYRROLIDONE/CARBON DIOXIDE
TETRAMETHYL AMMONIUM IODIDE

CODE	N	RK	RPK	P	C	D	X	W
32313.01	71	7.33	7.33	14.5				
32313.02	71	6.33	6.26	62.0				
32313.03	71	2.33	2.25	181.3				
32313.04	61	1.39	1.41	358.9				
32313.05	71	1.54	2.16	358.9				
32313.06	51	1.49	2.97	358.9				
32313.07	20	1.49	6.17	358.9	5.87	.53	2.0	72.
32313.08	400	1.83	29.02	358.9	43.86	5.04	6.0	2046.
32313.09	400	2.16	38.02	358.9	87.02	10.21	6.0	2199.
32313.10	400	2.97	41.75	358.9	126.27	14.03	6.0	2119.
32313.11	400	4.15	46.33	358.9	165.35	19.45	5.0	1998.
32313.12	500	4.01	48.01	358.9	315.61	37.25	6.0	2061.
32313.13	500	4.49	48.01	358.9	315.17	37.28	5.0	1997.
32313.14	502	11.93	50.09	358.9				
32313.15	501	37.64	50.09	358.9				
32313.16	601	45.13	50.09	358.9				

DIMETHYL SULFOXIDE/SULFUR DIOXIDE
ALUMINUM FLUORIDE

CODE	N	RK	RPK	P	C	D	X	W
26001.01	71	28.27	34.81	15.5				
26001.02	71	1.41	1.48	53.3				
26001.03	71	1.68	1.64	56.2				
26001.04	71	1.72	1.65	54.3				
26001.05	71	1.74	1.72	51.4				
26001.06	71	1.70	1.67	54.3				

DIMETHYL SULFOXIDE/SULFUR DIOXIDE
ALUMINUM CHLORIDE

CODE	N	RK	RPK	P	C	D	X	W
26002.01	431	9.49	9.66	15.5				
26002.02	400	11.38	12.30	53.3	16.06	1.39	4.5	366.
26002.03	61	14.01	14.01	56.2				
26002.04	421	14.01	14.01	54.3				
26002.05	410	13.30	13.30	50.4	32.75	4.78	.5	-122.
26002.06	31	10.43	10.17					

DIMETHYL SULFOXIDE/SULFUR DIOXIDE
ALUMINUM SULPHATE

CODE	N	RK	RPK	P	C	D	X	W
26003.01	0	1.44	3.10		29.10	3.53	6.0	1521.
26003.02	71	2.97	2.97					
26003.03	71	3.07	3.10					
26003.04	71	3.15	1.30					
26003.05	71	3.35	3.29					
26003.06	71	3.26	3.29					

DIMETHYL SULFOXIDE/SULFUR DIOXIDE
LITHIUM FLUORIDE

CODE	N	RK	RPK	P	C	D	X	W
26004.01	72	51.41	51.41					
26004.02	72	51.41	51.41					
26004.03	72	51.41	51.41					
26004.04	72	51.41	51.41					
26004.05	72	51.41	51.41					
26004.06	72	51.41	51.41					

DIMETHYL SULFOXIDE/SULFUR DIOXIDE
LITHIUM CHLORIDE

CODE	N	RK	RPK	P	C	D	X	W
26005.01	0	.15	.17		11.56	1.23	5.0	1662.
26005.02	30	.32	.34		5.09	.50	2.0	99.
26005.03	30	.43	.75		4.26	.41	1.5	63.
26005.04	30	.53	.56		3.57	.32	1.0	44.
26005.05	30	.61	.63		2.49	.19	1.0	39.
26005.06	30	.70	.73		1.63	.09	.5	28.

DIMETHYL SULFOXIDE/SULFUR DIOXIDE
POTASSIUM THIOCYANATE

CODE	N	RK	RPK	P	C	D	X	W
26009.01	72	51.41	51.41					
26009.02	71	8.56	7.92					
26009.03	71	5.29	5.42					
26009.04	71	6.90	4.45					
26009.05	71	15.54	14.76					
26009.06	20	.10	.10		1.53	.03	1.0	73.
26009.07	20	.20	.29		1.35	.01	1.0	73.
26009.08	21	.29	.20					
26009.09	21	.28	.21					
26009.10	31	.34	.28					
26009.11	31	.45	.52					
26009.12	21	.09	.09					

DIMETHYL SULFOXIDE/SULFUR DIOXIDE
SODIUM BROMIDE

CODE	N	RK	RPK	P	C	D	X	W
26010.01	71	1.05	1.08					
26010.02	61	.21	.31					
26010.03	71	.30	.35					
26010.04	71	.28	.32					
26010.05	71	.32	.36					
26010.06	71	.37	.41					

DIMETHYL SULFOXIDE/SULFUR DIOXIDE
SODIUM IODIDE

CODE	N	RK	RPK	P	C	D	X	W
26011.01	71	7.99	.74	14.5				
26011.02	61	.23	.57	52.3				
26011.03	61	.28	.45	58.2				
26011.04	40	.23	.32	54.3	2.34	.20	1.0	34.
26011.05	0	.26	.89	50.4	3.35	.33	1.0	41.
26011.06	0	.30	4.05	55.2	11.81	1.28	6.0	1077.

DIMETHYL SULFOXIDE/SULFUR DIOXIDE
SODIUM CHLORIDE

CODE	N	RK	RPK	P	C	D	X	W
26012.01	71	.94	1.18					
26012.02	71	.80	.86					
26012.03	71	.73	.79					
26012.04	71	.67	.88					
26012.05	71	.66	.79					
26012.06	71	.68	.86					

DIMETHYL SULFOXIDE/SULFUR DIOXIDE
TETRAMETHYL AMMONIUM CHLORIDE

CODE	N	RK	RPK	P	C	D	X	W
26013.01	72	51.41	51.41					
26013.02	72	51.41	51.41					
26013.03	72	51.41	51.41					
26013.04	72	51.41	51.41					
26013.05	72	51.41	51.41					
26013.06	72	51.41	51.41					
26013.07	72	51.41	51.41					
26013.08	72	51.41	51.41					
26013.09	72	51.41	51.41					
26013.10	72	51.41	51.41					
26013.11	72	51.41	51.41					
26013.12	72	51.41	51.41					

DIMETHYL SULFOXIDE/SULFUR DIOXIDE
TETRAMETHYL AMMONIUM IODIDE

CODE	N	RK	RPK	P	C	D	X	W
26014.01	61	.56	.61					
26014.02	71	.59	.61					
26014.03	31	.59	.82					
26014.04	10	.59	.70		1.78	.16	.5	10.
26014.05	30	.44	.73		1.65	.16	.5	4.
26014.06	21	.36	.29					
26014.07	61	.43	.43					
26014.08	61	.35	.38					
26014.09	61	.34	.35					
26014.10	61	.32	.32					
26014.11	61	.29	.30					
26014.12	71	4.77	.28					

DIMETHYL SULFOXIDE/SULFUR DIOXIDE
HYDROXYAMINE HYDROCHLORIDE

CODE	N	RK	RPK	P	C	D	X	W
26015.01	61	.25	.30					
26015.02	61	.23	.29					
26015.03	61	.32	.29					
26015.04	61	.34	.37					
26015.05	61	.32	.30					
26015.06	61	.29	.29					
26015.07	71	.34	.39					
26015.08	61	.28	.31					
26015.09	61	.26	.30					
26015.10	61	.22	.32					
26015.11	61	.27	.29					
26015.12	21	.09	.10					

DIMETHYL SULFOXIDE/SULFUR DIOXIDE
TRIMETHYLAMINE HYDROCHLORIDE

CODE	N	RK	RPK	P	C	D	X	W
26016.01	71	.56	.60					
26016.02	61	.47	.51					
26016.03	61	.41	.46					
26016.04	71	.43	.49					
26016.05	61	.32	.41					
26016.06	61	.31	.29					
26016.07	61	.30	.35					
26016.08	61	.23	.28					
26016.09	61	.23	.29					
26016.10	61	.24	.28					
26016.11	61	.21	.24					
26016.12	21	.09	.11					

DIMETHYL SULFOXIDE/SULFUR DIOXIDE
STANNOUS CHLORIDE

CODE	N	RK	RPK	P	C	D	X	W
26022.01	61	.16	.18					
26022.02	61	.13	.15					
26022.03	71	.15	.17					
26022.04	61	.15	.20					
26022.05	61	.14	.17					
26022.06	61	.14	.17					
26022.07	61	.20	.23					
26022.08	61	.15	.18					
26022.09	61	.15	.17					
26022.10	61	.16	.17					
26022.11	61	.15	.18					
26022.12	61	.14	.18					

DIMETHYL SULFOXIDE/SULFUR DIOXIDE
SODIUM TRICHLOROACETATE

CODE	N	RK	RPK	P	C	D	X	W
26026.01	61	.79	.87					
26026.02	71	.71	.77					
26026.03	71	.83	.89					
26026.04	71	2.27	.94					
26026.05	40	2.84	4.34		4.78	.11	3.5	620.
26026.06	400	1.77	33.91		86.80	9.23	6.0	2620.
26026.07	0	.83	26.84		45.13	5.16	6.0	2474.
26026.08	0	.65	16.37		27.79	3.10	6.0	2336.
26026.09	0	.61	12.62		25.45	2.82	6.0	2300.
26026.10	0	.56	9.17		15.28	1.59	6.0	1707.
26026.11	30	.56	4.77		4.44	.25	2.5	237.
26026.12	0	.10	.14		1.48	.12	.5	22.

DIMETHYL SULFOXIDE/SULFUR DIOXIDE
POTASSIUM TRICHLOROACETATE

CODE	N	RK	RPK	P	C	D	X	W
26027.01	71	3.88	5.02					
26027.02	71	3.47	5.06					
26027.03	71	3.05	4.37					
26027.04	71	3.66	5.36					
26027.05	71	3.26	[illegible].15					
26027.06	71	2.84	5.06					
26027.07	71	1.72	2.56					
26027.08	71	1.11	1.30					
26027.09	71	.98	1.17					
26027.10	71	.92	1.05					
26027.11	71	.90	1.05					
26027.12	71	.57	.10					

II. ELECTROMOTIVE CELL TESTS

(a) Membrane Cells. A number of test cells utilizing ion exchange membranes to separate the anolyte from the catholyte were built as shown in Table II on page 51.

In general, the membrane cells tested to date have suffered either from intermixing of the electrolytes, or from excessively high membrane resistance. As yet, the elimination of both of these effects in any single cell has not been accomplished. However, in view of the high potentials possible in anolyte-catholyte cells, search for better membrane materials will be continued; and test cells will be constructed as these become available.

The open circuit potentials for the systems utilizing glass membranes were obtained potentiometrically because of the high membrane resistance of these cells. This work has been discontinued due to the fragile nature of the structures required.

(b) Membrane Permeability. Water and ammonia penetration tests were performed on various types of membranes in anticipation of their possible use as separators and ion exchangers in hybrid solvent cells, specifically, the ammonia bronze anode/acid water cathode cell. This type of cell offers the possibility of single cell voltage in excess of 4.0 volts as already demonstrated by the 4.4 volt platinum/lithium bronze/potassium permanganate, sulfuric acid: water/carbon cell referred to in previous reports. The tests were conducted by clamping each membrane on the bottom of a glass tube (diameter = 1 inch) and adding a column three inches high of water to one and a column three inches high of ammonia to another. The membranes were then left in this apparatus for several hours and were checked periodically for solvent leakage. Most of the tested membranes failed, but three were found which may serve as ion exchangers and solvent separators as indicated in Table IV on page 52.

(c) Pilot Cells in Butyrolactone. Since butyrolactone was indicated in the solvent search as a possible choice for use in high energy batteries, pilot cells utilizing this solvent were built. The cells consisted of an anode, a cathode, and one or two sheets of separator material together with the electrolyte in a polypropylene envelope. The flat plate electrodes have a cross-sectional area of about 15 cm^2 and a thickness between 2 and 5 mm. The lithium anodes were pressed onto expanded magnesium alloy screen while expanded or perforated silver foil was used as the cathode current collector, "cathector."

Initial cell open circuit voltage was measured after addition of the electrolyte; the cell voltage at various loads was then obtained as shown in Table V on page 53.

These experiments were designed primarily to yield thermodynamic data from which the magnitude of cell potentials for various electrode materials in butyrolactone solvent could be predicted, and to give a comparative indication of the compatibility of the electrode materials with the solvent as well as the magnitude of initial polarization of the electrodes at various loads. On the basis of these test results, a few of the more promising couples will be chosen for study of electrode kinetics and electrochemical efficiency of the electrode materials.

(d) Pulse Catalysis of Aqueous Cathodes. A schematic of this approach is given in Figure VII, page 55. Preliminary testing is in progress, but no data is available at this time.

TABLE III

PILOT CELLS UTILIZING ION EXCHANGE MEMBRANES

Cell No.	Anode	Anolyte	Membrane	Catholyte	Cathode	o.c. Potential	Remarks
1	Mg/Li	Butyrolactone .25M KSCN	Gelman WB6403 Gelman WA6402	1M H_2SO_4	$KMnO_4$/C	3.8	Anolyte-catholyte intermixing.
2	Mg/Li	Butyrolactone .25M KSCN	Permion 1010	1M H_2SO_4	$KMnO_4$/C	4.2	Anolyte-catholyte intermixing.
3	Mg/Li	Butyrolactone .25M KSCN	Gelman WB6403	Butyrolactone $CuCl_2$*	$CuCl_2$/Cu	3.6	Anolyte-catholyte intermixing.
4	Mg/Li	Butyrolactone .25M KSCN	Permion 1010	Butyrolactone $CuCl_2$*	$CuCl_2$/Cu	3.7	No intermixing in 6 days; polarization 0.5v at 10^{-5} amp/cm^2.
5	Pt/Li-NH_3		Cationic glass	KCl**	AgCl/Ag	3.15	High cell resistance.
6	Pt/Li-NH_3		Gelman WA6402 Gelman WB6403	1M H_2SO_4	$KMnO_4$/C	4.4	Catholyte permeation of membrane.
7	Pt/Li-NH_3		Gelman WA6402	4M H_2SO_4/C		3.0	Catholyte permeation of membrane.
8	Pt/Li-NH_3		Gelman WA6402	4M H_2SO_4	$KMnO_4$/C	4.1	Catholyte permeation of membrane.
9	Pt/Li-NH_3		Gelman WA6402	NH_3, KSCN*	S:C/Ag	2.5	Catholyte permeation of membrane
10	Pt/Li-NH_3		Gelman WA6402	NH_3, NH_4SCN*	S:C/Ag	2.5	Loss of potential after 25 hours.

*Saturated Solution

**Aqueous Solution

TABLE IV

QUALITATIVE MEMBRANE PERMEABILITY TESTS

Membrane		Water Penetration	Ammonia Penetration
Gelman	WA6402	Rapid	Rapid
	WB6403	Rapid	Rapid
	WA6406	Rapid	Rapid
	SA6404	Rapid	Rapid
	SB6407	Rapid	Rapid
Nalco	D30	None	None
Ionac	XLMC3235	None	None
	XLMA3236	None	None
	MC3142	None	Slow, then rapid
	MA3148	None	Slow, then rapid
"AMFion"	C60	Slow, but steady	Slow, but steady
	C103	Slow, but steady	Slow, but steady
Whatman	P20	Rapid	Rapid
	CM50	Rapid	Rapid
	DE20	Rapid	Rapid
	AE30	Rapid	Rapid
	ET20	Rapid	Rapid

TABLE V

PILOT CELLS UTILIZING BUTYROLACTONE SOLVENT

Cell No.	Anode	Electrolyte	Cathode	Separation	Cell Potential, Volts o.c.	10KΩ	1KΩ	.5KΩ	.2KΩ	.1KΩ	Remarks
1	Li	LiCl*	mDNB:C/Ag	Whatman 42	2.5	2.3	2.0				
2	Li	LiCl*	PbO_2/Mg	Whatman 42	3.0	2.0					
3	Mg/Li	LiCl*	mDNB**/Ag	Whatman 42	2.3	1.7					
4	Mg/Li	KCl*	PbO_2/Ag	Whatman 42	3.5						
5	Mg/Li	LiCl*	PbO_2/Ag	Whatman 42	2.8	2.0					
6	Mg/Li	$AlCl_3$*	PbO_2/Ag	Whatman 1	3.2	3.2	3.0	2.8	2.5	2.1	
7	Mg/Li	$AlCl_3$*	Ni_2O_3/Ag	Whatman 1	2.5	2.5	2.4	2.3	2.2	2.1	
8	Mg/Li	$AlCl_3$*	S:C:NH_4SCN/Ag	M 1365	2.8	2.8	2.7	2.4			Anode noticeably attacked.
9	Mg	$MgSO_4$*	mDNB:C/Ag	M 1365	0.9	0.7					
10	Mg	LiCl*	mDNB:C/Ag	Whatman 541	1.5	1.2					
11	Mg	$AlCl_3$*	Ni_2O_3/Ag	Whatman 541	1.8	1.7	1.3				
12	Mg/Li	$AlCl_3$*	Ni_2O_3/Ag	Whatman 541	2.8	2.7	2.6	2.0		1.6	
13	Mg/Li	AlF_3*	Ni_2O_3/Ag	Whatman 541	2.9	2.5	1.4				
14	Mg/Li	KI*	$HgSO_4$/Ag	Whatman 541	2.4	2.4	2.4	2.3	2.1	1.5	
15	Mg/Li	2M KSCN	$HgSO_4$/Ag	Whatman 541	2.6	2.6	2.5	2.5	2.4	2.2	
16	Mg/Li	2M KSCN	$HgSO_4$:C/Ag	Whatman 541	2.7	2.7	2.6	2.6	2.5	2.5	
17	Mg	1M KSCN	$HgSO_4$:C/Ag	Whatman 541	0.9	0.9	0.8	0.7	0.7	0.6	
18	Mg/Li	1M KSCN	$HgSO_4$:C/Ag	Whatman 541	2.7					2.5	

*Saturated Solution

**Solution

TABLE V Continued

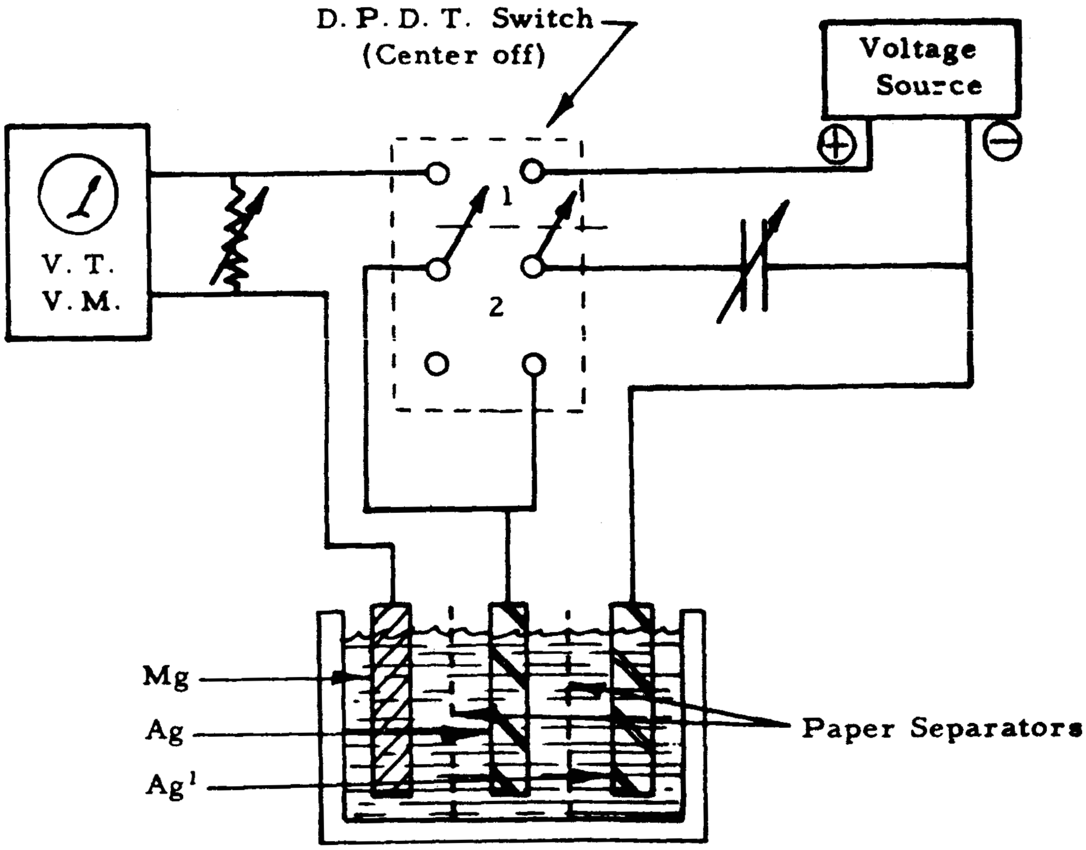
PILOT CELLS UTILIZING BUTYROLACTONE SOLVENT

Cell No.	Anode	Electrolyte	Cathode	Separation	o.c.	Cell Potential, Volts 10KΩ	1KΩ	.5KΩ	.2KΩ	.1KΩ	Remarks
19	Mg/Li	1M KSCN	$HgSO_4$:C/Ag	Whatman 541	2.7					2.4	
20	Mg/Li	.5M KSCN	$HgSO_4$:C/Ag	Whatman 541	2.7					2.5	
21	Mg/Li	.25M KSCN	mDNB:C/Ag	Whatman 541	2.9					2.6	Anode noticeably attacked.
22	Mg/Li	.25M KSCN	mDNB:C/Ag	Whatman 42	2.9					2.4	Anode noticeably attacked.
23	Mg/Li	.25M KSCN	N_2O_3/Ag	Whatman 541	2.7		2.7	2.6		2.3	
24	Mg/Li	.25M KSCN	mDNB:C/Ag	Whatman 541	2.9					2.7	Anode noticeably attacked.
25	Mg	.25M KSCN	2, 4-DNT:C/Ag	Whatman 541	0.9	0.9	0.8	0.6		0.4	Anode noticeably attacked.
26	Mg/Li	.25M KSCN	2, 4-DNT:C/Ag	Whatman 541	2.9					2.4	Anode noticeably attacked.
27	Mg/Li	.25M KSCN	S:C/Ag	M 1365	2.8	2.8	2.6	2.5		2.1	Purple color on discharge.
28	Mg/Li	.25M KSCN	S:C/Ag	Whatman 541	3.2	2.7	2.6	2.5		2.1	Purple color on discharge.
29	Mg/Li	.25M KSCN	S:C/Ag	Whatman 42	2.8	2.6	2.5	2.4	2.2	2.1	Purple color on discharge.
30	Mg/Li	.25M KSCN	$CuCl_2$:C/Ag	Whatman 42	3.2	3.2	3.2			3.0	Deep purple on discharge.
31	Mg/Li	.25M KSCN	$CuCl_2$:Cu/Ag	Whatman 42	3.2	3.2				3.0	Deep purple on discharge.
32	Mg/Li	.25M KSCN $CuCl_2$*	$CuCl_2$:Cu/Ag	Whatman 541	2.7		2.6	2.6		2.2	Anode strongly attacked.
33	Mg/Li	.25M KSCN	MgO:Mg/Mg	Whatman 541	2.0	1.9	1.5				
34	Mg/Li	.25M KSCN	MgO:C/Mg	Whatman 541	2.4	2.4	2.3	2.2	2.0	1.9	
35	Mg/Li	.25M KSCN	AlF_3:C/Ag	Whatman 541	2.9	2.9	2.7	2.6	2.4	2.2	

*Saturated Solution

Pulse Catalysis Cell Schematic

FIGURE VII



Electrolyle = $Mg(ClO_4)_2$ in H_2O saturated with MgO

In position (1) the Mg and the Ag electrodes are connected through the variable resistance box, and the capacitor is being charged by the voltage source. In position (2) the Mg and the Ag electrodes are disconnected, and the capacitor is discharging through the Ag and the Ag^1 electrodes with the discharge polarity such that a positive charge is set up on the Ag electrode.

III. ELECTROMOTIVE CELL TESTS USING LIVINGSTON BATTERY HARDWARE

A series of single cell tests has been conducted making use of Livingston battery hardware having the dimensions 2.6 inches in diameter by 2.7 inches high. The components of this system are Mg/KSCN/mDNB (meta-dinitrobenzene) in liquid ammonia. Most of the tests were conducted at a temperature of -50°C. The Mg/mDNB couple has a theoretical energy content of approximately 800 watt hours per pound based on eight faradays per mol of mDNB and two faradays per mol of magnesium. In previous ammonia work, only a small fraction of this energy has been utilized (in the order of one or two faradays per mol of mDNB). In the current work, various amounts of silica gel were added to the cathode mixture for the purpose of removing water, a probable reaction product, which is known to interfere seriously with the efficiency of the magnesium anode in liquid ammonia. It was also predicted that the removal of water from the system might have a pronounced effect upon the capacity of mDNB as an oxidizer in liquid ammonia. Although some increase in cathodic efficiency was obtained by this method (see Figure VIII, page 56) more effective techniques for improving the utilization of mDNB in non-aqueous solvents are being sought.

Cells of the type Mg/KSCN:NH_3/S:C:NH_4SCN are being studied. A net weight efficiency (exclusive of container and electrolyte) of 95 watt hours per pound was achieved in one cell by the use of a cation exchanger membrane. The results obtained from other cells of this type are presented in Table VI, page 57, and Figure IX, page 58.

New cathode containers have been designed in which ceramic cylinders and ion exchange membranes will be used in an attempt to reduce internal transfer of cathode active material to the magnesium anode.

EFFECTS OF SILICA GEL

Batteries in Hardware
Type 604-B-Load = 15 ohms
Mg/KSCN/mDNB/c/Ag

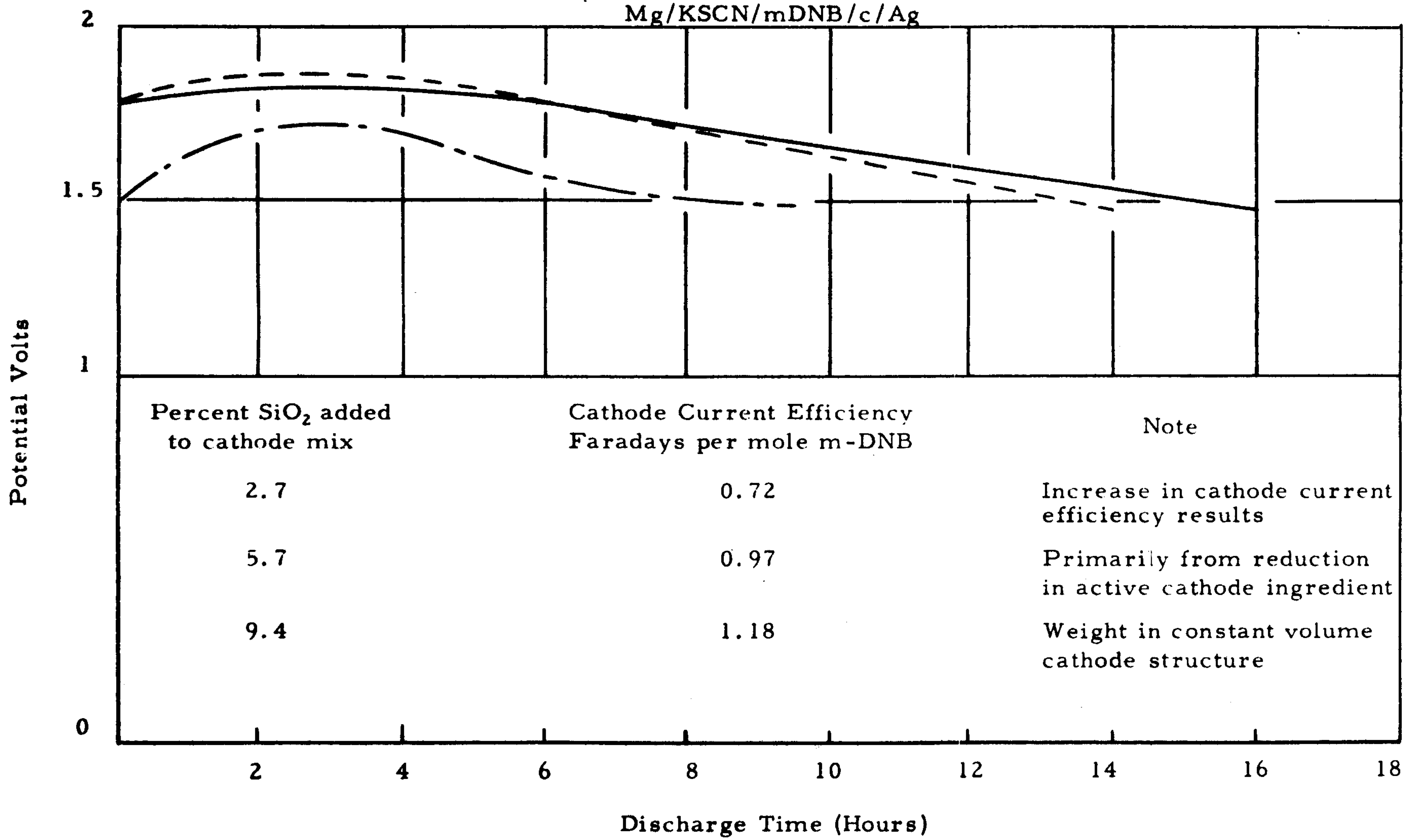


FIGURE VIII

TABLE VI

PERFORMANCE OF Mg/KSCN:NH_3/S:C:NH_4SCN/Ag CELLS

Cell No.	Cathode Mix Ratio	Discharge Time, Hours	Av. emf	Av. Drain Rate, ma.	Coulombs	Coulombs/gram Cathode Mix	Coulombs/gram Sulfur	Cathode Eff, %	Net wh/lb.	wh
97	1	40	1.40	14.0	2010	503	1260	20.9	54.3	0.78
100	1	53	1.61	16.1	3070	768	2075	31.8	95.3	1.37
104	1	42	1.45	16.9	2550	638	1595	26.4	71.4	1.02
107	1	54	1.41	14.1	2770	693	1735	28.8	75.0	1.08
101	2	47	1.55	15.5	2610	654	1765	29.2	78.4	1.12
102	2	38	1.49	14.9	2050	513	1390	23.0	58.9	0.84
103	2	40	1.50	15.4	2170	542	1465	24.4	63.3	0.91
106	2	44	1.38	13.8	2190	547	1475	24.6	58.6	0.84
108	3	53	1.39	13.9	2660	665	1995	33.1	71.3	1.03

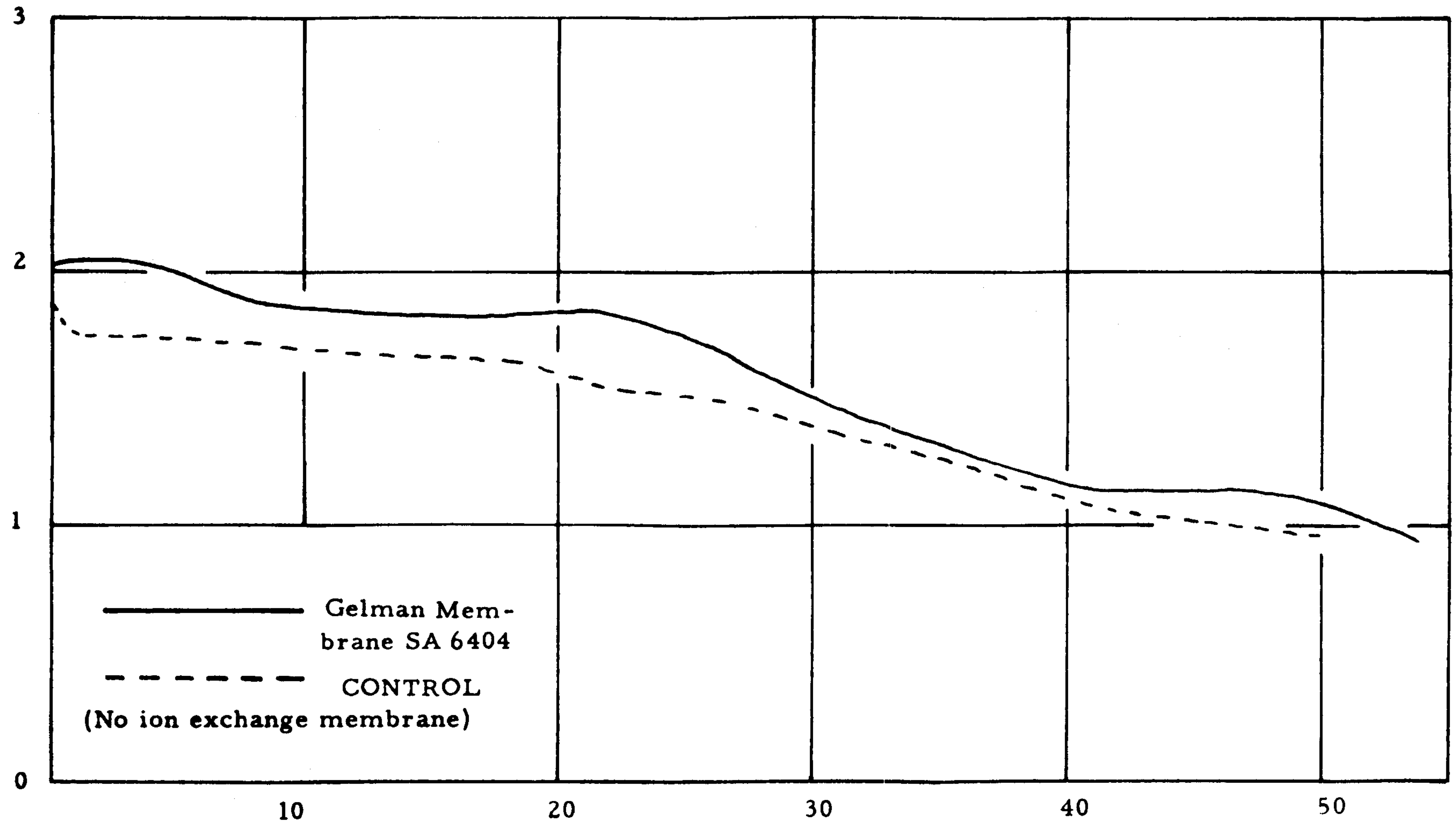
CATHODE MIX RATIOS:

1 - S:C:NH_4SCN = 1:1:0.5

2 - S:C:NH_4SCN = 1:1:0.7

3 - S:C:NH_4SCN = 1:1:1

FIGURE IX



DISCHARGE CHARACTERISTICS OF

$Mg/KSCN:NH_3/NH_4SCN:S:C$ CELLS

IV. RESEARCH CELL AND SEPARATOR RESISTANCE MEASUREMENTS

The application of half-cell and reference electrode techniques in varying solvents and under various atmsopheric conditions is subject to practical and theoretical difficulties. One technique for overcoming many of these problems is the use of two pairs of electrodes within the same envelope. Equipment has been designed and constructed during the quarter to make extensive use of this approach.

The technique consists of constant average driven discharge of the cells under a cyclic loading program allowing frequent measurements of open and closed circuit voltages of the complete cell and its individual components as resolved by two reference or auxilliary unloaded electrodes. The two extra electrodes permit division of the complete cell into two half-cells and provide an index of their mutual reliability by comparison of one to the other. Frequent verification of references is necessary for sealed cells and for cells of unusual solvents. In addition, the load current may be chopped at a comparatively high frequency during the load-on half of the duty cycle to provide equally comprehensive ac measurements for cell component resistance evaluation. Since about 16 different measurements are required on a continuous basis, an automatic strip chart recording system is required.

A schematic diagram of the approach which has been formulated for this work is given in Figure X, page 63. The symbols E_2, E_3, etc. refer to the various atuomatic recorder functions listed in Table VII, page 64. A color-coded strip chart recorder was chosen as the basic instrument. The functions of this basic instrument are determined in accordance with an external scanning system on a 52-point repetitive cycle to allow for four color coding of the 26 data channels. Alternating current data and cell current are displayed starting from the right-hand edge of the chart extending to the left-hand edge. Direct current voltages are displayed on a zero center scale to accommodate polarity reversal. Since driven discharge is used, exhaustion of one electrode need not terminate measurement of the remaining electrode and the advantages of half-cell technique are retained. Figure XI, page 65, is the schematic diagram of the external stepping switch circuit used to provide this scanning sequence.

Concerning the cell discharge load current wave form, two frequencies are of basic importance. First is the basic on-off repetition rate. It is planned to use a value in the order of twenty seconds, i. e., ten seconds on, 10 seconds off. Each of the four cell terminal combinations will be scanned at the end of a load-on half-cycle and at the end of a load-off half-cycle. The load pattern will, therefore, be orthogonal; and each reading will have a comparable history. The average load current over the entire on-off cycle will be one half of the value for the fifty per cent on-period. The load-on period will also be interrupted, but at a higher repetion rate to retain polarization loss during the short but repetitive off-periods of the basic load-on period. The load-off sub-periods will be of relatively short duration compared to the load-on sub-period.

The current regulator system if so relatively high impedance so as to hold the load current pulses relatively square and of a fixed peak and average value.

Research Cell Recorder (Half Cell Tests)

The schematic of the load control device (current control chassis) is given in Figure XII, page 66. The current delivered to the working electrodes of the test cells is fed to the stepper switch circuit via terminals Nos. 6 and 7. The high voltage present in the current control is limited at this point to ± six volts by the two 6-volt zenner diodes. The two 6L6 vacuum tubes serve as grid-control rectifiers and the constant current generators simultaneously. The value of current supplied is determined by the 10 kilohm potentiometer connected to the control grids of the 6L6's, and keying is accomplished via terminals Nos. 5 and 26 leading to the stepper switch system. These terminals are alternately shorted and off-circuited by switch deck No. 1 of the stepper switch circuit. Consistency of the various wave form values are maintained by the three gaseous regulator tubes OA3, OD3, and OD3. Equality of wave form is adjusted by means of the 100 ohm potentiometer connected between the two cathodes. The 60-cycle sine input of the power line is transformed to 270 volts rectified and, in effect, clipped to produce a series of nearly square pulses interspersed by short off-periods. It is to be noted that this output is not filtered within the circuit. Such filtering action as the cell provides serves as a measure of the internal ohmic resistance of the cell. This effect is calibrated so as to provide an equal response ac and dc when measuring a fixed resistance rather than the cell. Figure I on page 2 is a photograph of a recording of the first non-aqueous cell tested with this particular instrumentation.

Recorder Channel No. 2 displays the open circuit voltage of the working electrodes at the end of the load-off half cycle.

Recorder Channel No. 1 similarily displays the working electrode closed circuit voltage. Note that at the right-hand edge of the data the separation between the open circuit and closed circuit conditions is relatively small; and at the left-hand side, just prior to decay of the open circuit cell voltage, a substantial separation occurred.

Recorder Channel No. 10 displays the anode open circuit voltage and visually explains the sharp decline of the cell open circuit voltage.

Recorder Channel No. 9 of Figure I, page 2, shows the closed circuit potential of the anode and indicates that the majority of the decline of cell voltage under load is due to losses associated with the anode.

Recorder Channels Nos. 5 and 6 confirm that the cathode resistance and polarization were negligible throughout the discharge of this cell.

Recorder Channel No. 17 serves to monitor the potential of the reference electrodes by comparing one to the other with the cell on open circuit. Channel No. 16 measures the potential of the reference electrodes when the working electrodes are drawing current. The cell current produces IR drops. In the usual configuration, the reference electrodes will be sensitive to the electrolyte portion of the IR drop; and the difference between Channels Nos. 16 and 17 will represent this decrease.

The ac scales of Figure I, page 2, are expanded by a factor of 3 over the dc values in order to make them clearly legible. In addition, the ac scales, being non-polar, may extend over the full chart width, that is, height on Figure I. Recorder Channel No. 3 constitutes the ac voltage developed between the working anode and cathode. Knowing the current (Recorder Channel No. 14), this may also be converted to an equivalent resistance figure.

The cathode ac voltage is displayed by Recorder Channel No. 7, and, as might be expected from Channels Nos. 5 and 6, is negligible.

Recorder Channel No. 11 displays the anode ac voltage which constitutes the majority resistance factor in this cell.

Recorder Channel No. 18 displays an ac Haring voltage developed between the reference electrodes and should be comparable to the separation between Channels Nos. 16 and 17 with the distribution of electrodes indicated by the cell in the stepper switch circuit diagram.

It is hoped that this convenient and direct display of the cell data in the machine printed form will facilitate rapid progress in the testing and evaluation of new and unusual cell compositions.

FIGURE X

SCHEMATIC DIAGRAM OF MULTIPLE RECORDING SYSTEM TO FACILITATE 1/2 CELL STUDIES IN VARIOUS MEDIA

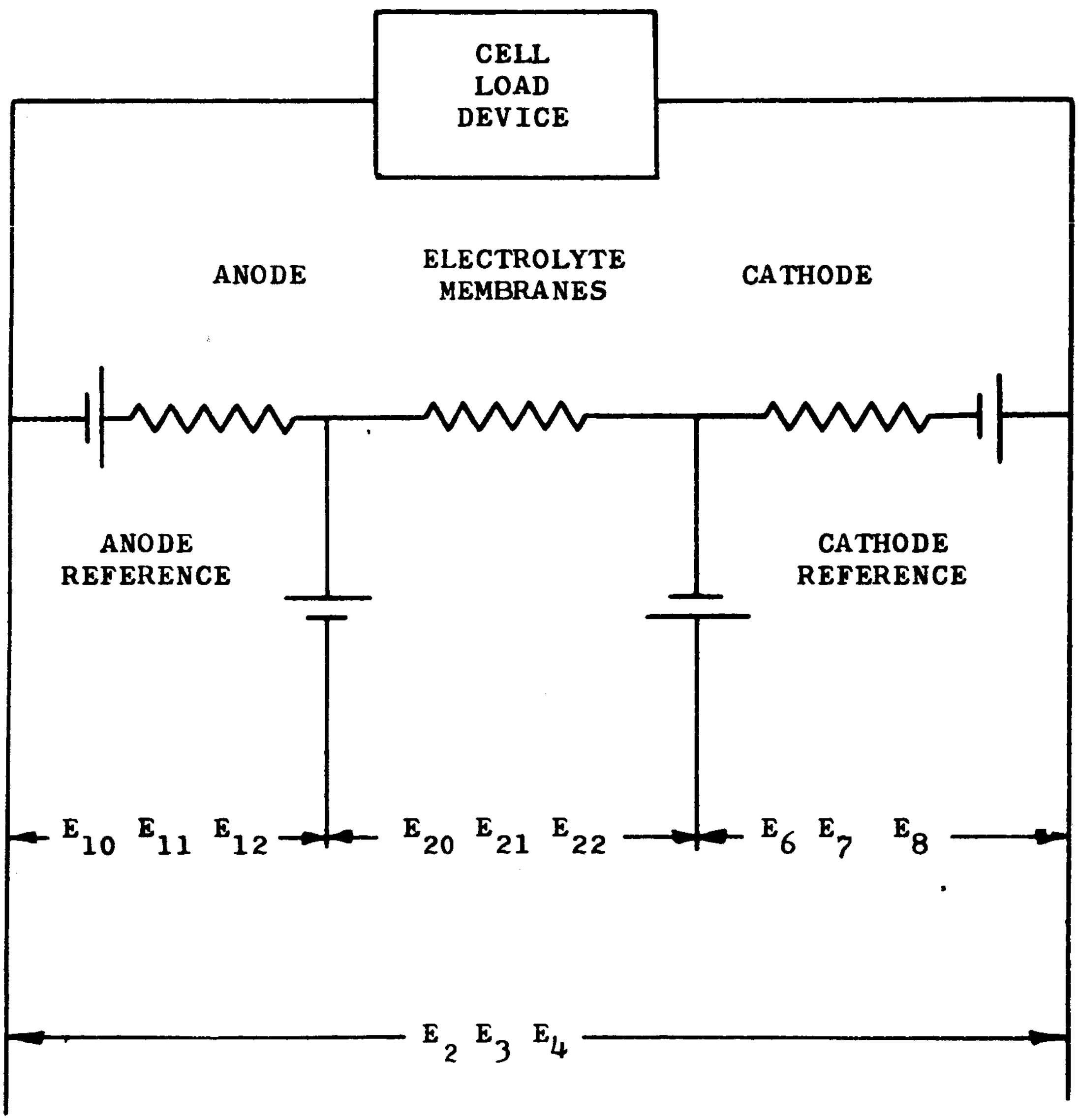


TABLE VII

RESEARCH CELL RECORDER FUNCTIONS

Scanner Position	Recorder Channel	Load	Scale Origin	Color Code (a)	Scale Type	Signal Source
1	0	0	$\frac{1}{2}$	P	----	Open Circuit
2	1	+	$\frac{1}{2}$	R	d. c.	Cell
3	2	0	$\frac{1}{2}$	R	d. c.	Cell
4	3	+	0	R	a. c.	Cell
5	4	0	0	R	----	Short
6	5	+	$\frac{1}{2}$	G	d. c.	Cathode
7	6	0	$\frac{1}{2}$	G	d. c.	Cathode
8	7	+	0	G	a. c.	Cathode
9	8	0	0	G	----	Short
10	9	+	-	P	d. c.	Anode
11	10	0	$\frac{1}{2}$	P	d. c.	Anode
12	11	+	0	P	a. c.	Anode
13	12	0	0	P	----	Short
14	1	+	$\frac{1}{2}$	G	d. c.	Cell
15	2	0	$\frac{1}{2}$	G	d. c.	Cell
16	3	+	0	G	a. c.	Cell
17	13	0	0	G	----	Short
18	14	+	0	G	d. c.	Current
19	15	0	0	R	----	Reserved
20	16	+	$\frac{1}{2}$	R	d. c.	Reference Electrode
21	17	0	$\frac{1}{2}$	R	d. c.	Reference Electrode
22	18	+	0	R	a. c.	Reference Electrode
23	19	0	0	R	----	Short
24	14	+	0	P	d. c.	Current
25	20	0	$\frac{1}{2}$	P	----	Reserved
26	21	+	$\frac{1}{2}$	P	----	Reserved
1	0	0	$\frac{1}{2}$	P	----	Open Circuit

(a) R = red, G = green, P = purple

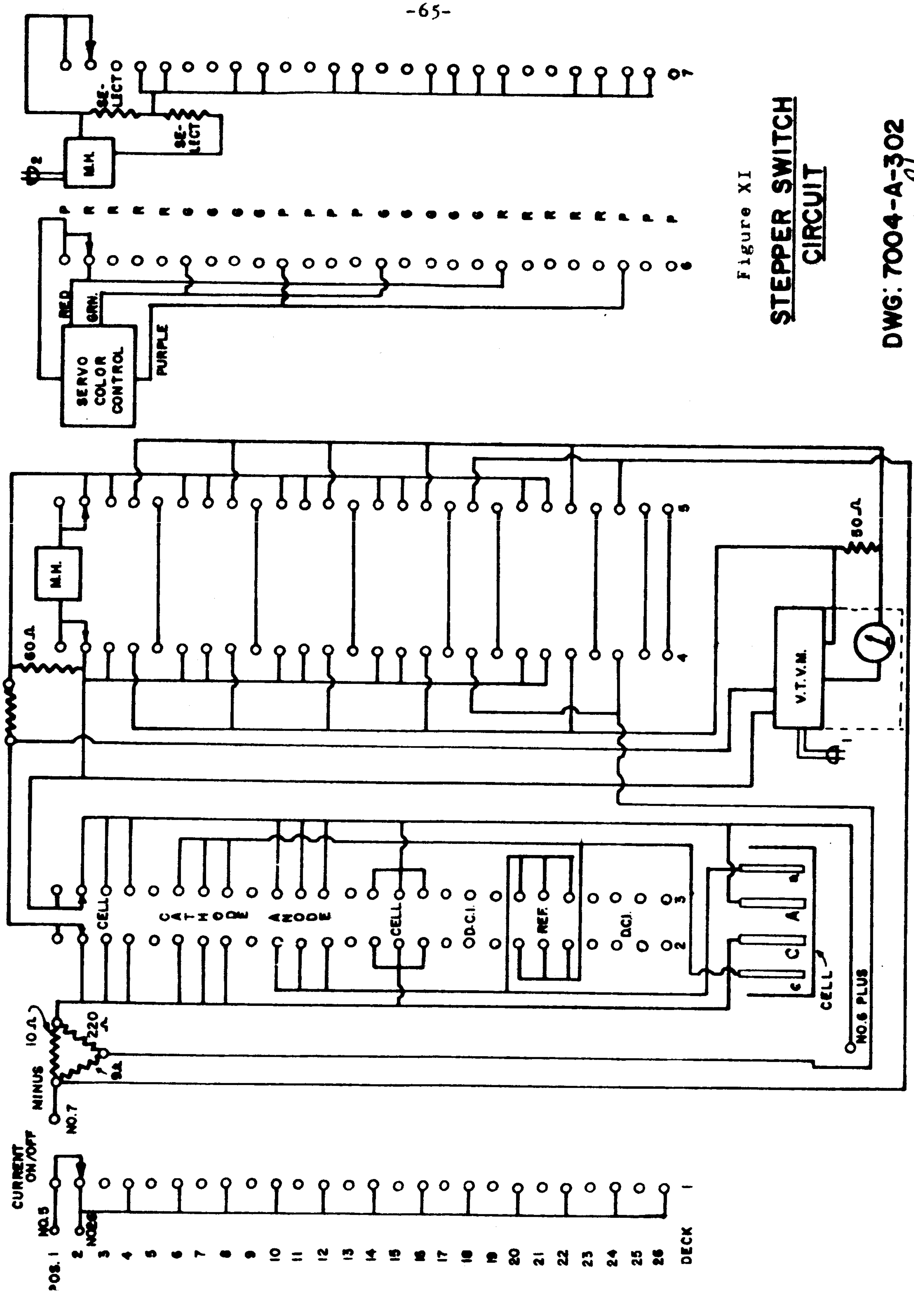
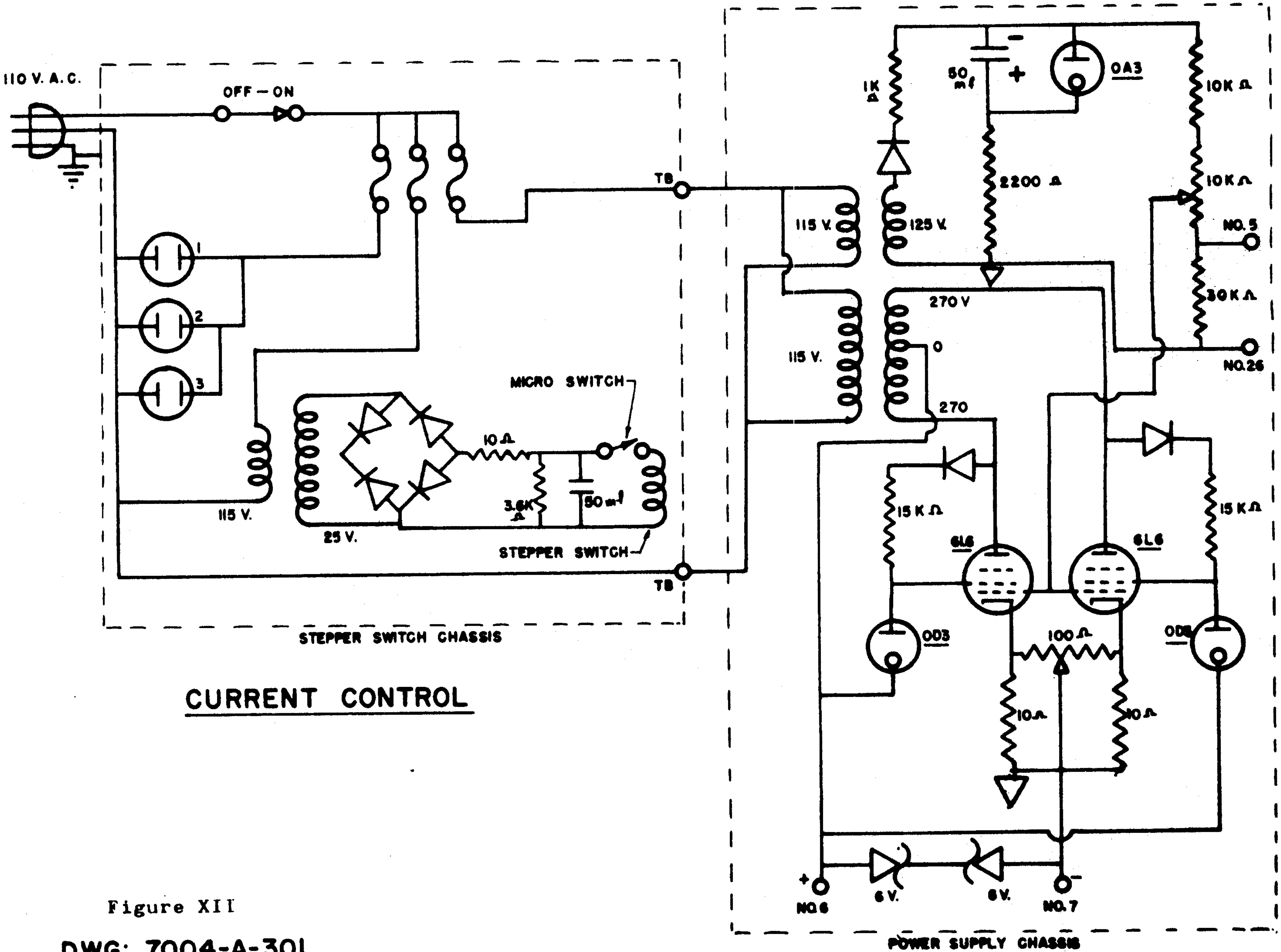


Figure XI

STEPPER SWITCH CIRCUIT

DWG: 7004-A-302

2-3-64



CURRENT CONTROL

Figure XII

DWG: 7004-A-301

Rel 3-2-64

V. MATERIALS COMPATIBILITY EVALUATION

Considerable work has been done to determine the compatibility of ion exchange membranes, separators, and materials of construction when immersed in solvents saturated with various salts under ammonia, sulfur dioxide, and carbon dioxide atmospheres. A summary of the results during the quarter may be found in Table VIII, page 69, and under Comments below. The identification of materials may be found in the Appendix, pages .

Comments

The following materials were visually satisfactory in all of the tests to which they were subjected: Whatman ion exchange membranes DE-20 and P-20 (electrochemical effects unknown); Whatman No. 42 filter paper; M-1365 (cotton with Chandler binder); M-1406 (Nylon with Dynel binder); R-2205 (cellulose); polypropylene (EM-476, sheets and test cells); polyethylene; Aclar 33C (fluorohalocarbon resin); sterling silver; Teflon insulation; aluminum alloy (No. 3003 - H114); magnesium alloy (No. AZ31B0); and silicone rubber.

Those materials which were found to be visually satisfactory in all but one or two systems are: Whatman ion exchange membranes ET-20, AE-30, and CM-50 (with the possible exception of some chemical alteration of the resins); Viscose (M-1216 and M-1231); Devcon eposy adhesive; Nylon; silver plating; and stainless steel (type 302).

The following materials were unsatisfactory in many cases: the Ionac ion exchange membranes; EM-470 (Dynel); Nalco D-30 (vinyl); A-12 epoxy resin; tin plating; vinyl insulation; and copper.

The polypropylene cells have withstood all tests very well except for a yellow discoloration which developed in the liquid anion exchanger-ammonia and benzene-sulfur dioxide systems.

The nitrile rubber "O" rings (No. 488-70) that are used to seat the steel pressure chambers are satisfactory for use with ammonia and some other gases, buth they were attacked by sulfur dioxide. The manufacturer recommended butyl rubber (No. 805-70) for use with the latter gas.

Code and Notes to Table VIII

CODE

C = Compatible

I = Incompatible

Q = Questionable

P. C. = Propylene Carbonate

P. E. = Polyethylene

P. P. = Polypropylene

S. S. = Stainless Steel

The use of "Q" as applied to ion exchange membranes indicates that the physical appearance is relatively good. However, the chemical effect on the efficiency of the resins as ion exchangers may be determined best by testing them in battery cells.

a = The vinyl insulation shrank in length.

b = Light yellow color developed; color removed by cleaning and drying.

c = White film formed on aluminum sheet; some pitting took place.

d = Permanent light yellow color.

e = Dark gray surface film.

f = Surface etched.

g = Nylon turned black and became soft to a considerable depth.

h = Dark brown stain.

i = Gray coating, especially at edges, that can be scraped off.

j = Fabric dissolved or disintegrated.

k = Swelled and softened badly.

l = Trace of corrosion.

r = Part or all of resin removed.

TABLE VIII

MATERIALS COMPATIBILITY

Atmosphere	Ammonia Gas at Room											
Pressure	120 psig							120 psig			30 to	
Solvent	Liquid Anion Exchanger, "LA-1"							2-Ethanolpyridine				
Solute	None	$AlCl_3$	LiF	LiCl	NaI	KBr	$(CH_3)_4$-NCl	None	$AlCl_3$	LiF	LiF	LiCl
Duration, days	2	4	4	4	4	4	4	4	4	4	9	9
1 SA-6404												
2 MC-3142												
3 MA-3148												
4 XLMC-3235												
5 XLMA-3236												
6 ET-20												
7 AE-30												
8 DE-20												
9 P-20												
10 CM-50												
11 Whatman 42	C											
12 EM-470	I											
13 M-1216												
14 M-1231	C											
15 M-1365	C											
16 M-1406												
17 R-2205	C											
18 EM-476												
19 P.P. Sheet	C											
20 P.P. Cell	C	C	C	C	C	C	C	C	C	C	C	C
21 P. E.	C	C	C	C	C	C	C	C	C		C	C
22 Nalco D-30	I											
23 Aclar-33C												
24 A-12 Epoxy												
25 Devcon												
26 RTV-11												
27 Nylon Rod	C	C	C	Cd	C	Cd	C	C	C		C	C
28 Ag Tube	C											
29 Ag Plating	C	C	C	C	C	C	C	C	C	C		C
30 Teflon Insul.	C	C	C	C	C	C	C	C	C	C		C
31 Sn Plating	C	C	C	C	C	C	I	I	C	I		C
32 Vinyl Insul.	C	C	C	C	C	C	Ia	Ia	Ia	Ia		Ia
33 Copper									I	I		
34 Al Sheet	C	Ci	Ci	Ci	C	C	C	C	C		C	Ci
35 S. S. Sheet	C	C	C	C	C	C	C	C	C	C		C
36 Mg Alloy												

(Code, notes and comments on pages 67 and 68.)

EVALUATION

	Temperature						Sulfur Dioxide at Room Temperature							CO_2
	90 psig			85 psig			32 psig							85 psig
				Pyridine			Benzene							P. C.
	KBr	NaI	$(CH_3)_4$-NCl	None	$AlCl_3$	$(CH_3)_4$-NCl	None	$AlCl_3$	LiCl	NaI	KBr	$(CH_3)_4$-NCl	LiF	None
	9	9	9	7	7	4	5	5	5	2	2	2	5	11
1				Cr	Ir	Q								Qr
2				Ir,j	Ir,j	Ir								
3				Ir,j	Ir,j	Ir								Qr
4				Ir	Ir	Ir								Qr
5				Ir	Ir	Ir								Qr
6				Q	Qr	Q								Q
7				Q	Qr	Q								Q
8				Q	Q	Q								Q
9				Q	Q	Q								Q
10				Q	Qr	Q								Q
11		C	C	C	C	C	C	C	Cd	Ch	C	C	C	C
12		C	C	Ij			I	I	Id	I	I	I	I	
13		C	C				C	C	Q	I	C	C	C	C
14		C	C	C	C	Ij	C	C	C	C	C	C	C	C
15		C	C				C	C	C	C	C	C	C	C
16														C
17		C	C	C	C	C	C	C	C	C	C	C	C	C
18				C		C								C
19							C	C	C	C	C	C	C	
20	C	C	C	C	C	C	Cb	Cb	Cb	Cb	C	C	Cb	C
21	C	C	C	C		C	C	C	C	C	C	C	C	C
22					Ij	Ij	I	Id	Id	Ih	I	I	I	Ij
23				C	C	C								C
24				Ik	Ik									C
25						I								C
26														C
27	C	C	C	C	C	C	C	C	Cd	Ig	C	C	C	C
28							C	C	C	Ce	C	C	C	
29	C	C	C	C	C	C	C	C	C	I	C	I	C	C
30	C	C	C	C	C	C	C	C	C	C	C	C	C	C
31	C	C	C	C	I	C	C	C	I	I	C	I	I	C
32	Ia	Ia	Ia	Ik	Ik	Ik	Ia	Ia	Ia	Ia	Ia	Ia	Ia	Ia
33				I	I									C
34	C	C	C	Ci	Ci	Ci	C	C	C	Cc	C	Ci	Cc	Ci
35	C	C	C	C		C	C	C	C	Cf	C	C	C	C
36				Cl	Ci	Cl								Ci

PART C

WORK TO BE DONE

During the Next Month

The solvent-atmosphere concept has broadened the horizon of possible systems which might be evaluated for high energy density performance to the point where an arbitrary cutoff of the examination of new systems is called for. Despite the fact that only four atmospheres have been examined and there are many additional liquids which have merit (dimethylsulfoxide-SO_2 is indicated) this work will be discontinued during the tenth month and the untreated data will be computed. Any new, useful solvent-atmosphere systems revealed will be added to the cell task list.

Research cell testing and the utilization of the basic data which has been obtained will be emphasized.

It was observed that the difference in potential between cells using lithium anodes and cells using magnesium anodes in butyrolactone and a normal atmosphere were consistantly two volts apart. In water, this difference is closer to one volt. Correction of electrode potentials for the effect of the solvent is a major factor. In addition, our attempts to obtain data from the literature to use in estimating these corrections has not been successful. Consequently, it was decided to defer further theoretical consideration of electrodes and to concentrate on the collection of research cell data.

During the Last Quarter

During the las quarter, we will have the opportunity to put the results of the literature search, theoretical studies, measurements, and preliminary cells to the acid test of building batteries in a selected number of electrochemical systems, each having a reasonable theoretical promise of providing performance at or above the 200 watt hour per pound level.

SOLVENT-SOLUTE-ATMOSPHERE CODE

SOLVENT CODE

01	n-Butylamine	22	Phenyl Ether
02	Ethyl Acetate	23	N-Methyl 2-Pyrrolidone
03	Propylene Carbonate	24	Hexylene Glycol
04	Acetone	25	1-Fluoro-2, 4-Dintrobenzene
05	Benzene	26	p-α-Dichlorotoluene
06	Toluene	27	2-Amino 3 Ethylpyridine
07	Pyridine	31	Acetonitrile
08	Tetrahydrofuran	32	Dioxane
10	1, 1, 1-Trichloroethane	33	Ethylene Carbonate
11	iso-Propylamine	35	Para Chlorobenzotrifluoride
12	Petroleum Ether	41	N, N-Dimethylformamide
13	Butyrolactone	51	Formamide
14	Methanol	60	Dimethyl Sulfoxide
15	Flurobenzene	95	Water
16	p-Fluorotoluene	96	Ammonia
17	2-Ethanolpyridine	97	Mercaptopropionic Acid
20	Nitromethane	98	Amberlite LA-2
21	n-Propylamine	99	Amberlite LA-1

SOLUTE CODE

1.	AlF_3	10.	NaBr	19.	KF
2.	$AlCl_3$	11.	NaI	20.	$MgSO_4$
3.	$Al_2(SO_4)_3$	12.	NaCl	21.	$AgNO_3$
4.	LiF	13.	$(CH_3)_4NCl$	22.	$SnCl_2$
5.	LiCl	14.	$(CH_3)_4NI$	23.	$(C_6H_5)_2CO$
6.	KBr	15.	$HONH_2 \cdot HCl$	24.	$C_6Cl_4O_2$
7.	KI	16.	$(CH_3)_3N \cdot HCl$	25.	$Mg(ClO_4)_2$
8.	KCl	17.	$MgCl_2$	26.	$NaCO_2CCl_3$
9.	KSCN	18.	$MgBr_2$	27.	KCO_2CCl_3

ATMOSPHERE CODE

0	Air	2	Sulfur Dioxide
1	Ammonia	3	Carbon Dioxide

REFERENCE NO. 1 LITERATURE REVIEWED

Log of Report Numbers

Card Col. 4 5 6	Report On: Column 3 Code Entry 1
0 0 1	"List of Lithium Compounds and of Many Other Chemicals", City Chemical Corporation.
0 0 2	"Trichloroethylene and Other Electronic Chemicals", Mallinkrodt Chemical Works.
0 0 3	"Trifluoroacetic Acid", Halocarbon Products Corporation.
0 0 4	"A.C.S. Meeting Program - New York, September, 1963.", C&EN - 6/17/63, pgs. 80 to 89. Also C&EN 8/5/63.
0 0 5	"Impregnated Filter Paper Traps Radioactive Debris", C&EN - 5/27/63, pg. 45.
0 0 6	"Ion Exchange", Helferich, C&EN - 3/25/63, pg. 65.
0 0 7	"Immiscible Systems Since 1934", S.L. Kittsley Review, C&EN - 4/8/63, pg. 112.
0 0 8	"Pesticides Called Biological Dynamite", C&EN - 8/5/63. pg. 34.
0 0 9	"Electrode Separators for Batteries", Ger. Pat. 1,143,874, CA59-1-7/8/63-224b.
0 1 0	"Electronegativity of Hydrocarbons Determined", C&EN - 8/19/63, pg. 46.
0 1 1	"Activity Measurements in the Precathodic Layer with the Aid of the Glass Electrode", CA59-2-7/22/63-1270e.
0 1 2	"The Theory of Porous Electrodes", CA59-2-7/22/63-1271f.
0 1 3	"Theory of the Polymetallic Electrode in Any Electroactive Medium", CA59-2-7/22/63-1273a.
0 1 4	"Effect of Ligand Field on Oxid.-Reduc. Properties of Compounds of Transition Elements", CA59-2-7/22/63-1281a.
0 1 5	"Faradic Rectification Study of Effect of Nonpolar Liquids on Transfer Coeff. and Kinetics of Redox Processes", CA59-2-7/22/63-1288h.
0 1 6	"Observations on the Electrochemical Behavior of Organic Solutions of Aliphatic Trialkylamine Salts", CA59-3-8/5/63-2395f.

Log of Report Numbers

Card Col. 4 5 6	Report On:	Column 3 Code Entry 1
0 1 7	"Anodic Oxidation of Triethylamine", CA59-3-8/5/63-2395e.	
0 1 8	"The Mechanism of Electrodeposition from Aqueous Solutions of Square-Planar Complexes", CA59-3-8/5/63-2398g. Also see CA59-4-8/19/63-3530e, and J. Electrochem. Soc. 110 (7), 716-23 (1963).	
0 1 9	"Electromotive Force Measurements of Metal-Oxygen Systems", CA59-3-8-5-63-2398h.	
0 2 0	"The Maximum Rate of Diffusion of Electrolytic Hydrogen Through Palladium and Palladium-Silver Alloy Diaphragms", CA59-3-8/5/63-2398h.	
0 2 1	"Electrochemical Tretment of Solutions", CA59-3-8/5/63-2400e.	
0 2 2	"Electrochmeical Reaction Apparatus", CA59-3-8/5/63-2400f.	
0 2 3	"Interrelation Between Thermodynamic, Electronic, and Electrochemical Properties of Metals. II. Relation Between Voltage and Free Energy", CA59-4-8/19/63-3525e.	
0 2 4	"Mechanism and Kinetics of the Electrode Reactions of Metal Complexes", CA59-4-8/19/63-3526h.	
0 2 5	"Electroplating of Plastics", CA59-4-8/19/63-3529g.	
0 2 6	"Mechanism of Electrodeposition of Metals from Liquid Ammonia Solutions", CA59-4-8/19/63-3530f.	
0 2 7	"Influence of Solvent Composition on Electrode Potentials", CA-59-4-8/19/63-3532c. I - Potentials of Single - And Polycrystalline Zn Electrodes in 1,4-Dioxane Water - $ZnSO_4$ Mixtures II - Potentials of Single - And Polycrystalline Zn Electrodes in Ethanol-Water $ZnSO_4$ Mixtures. III - Potentials of Single - And Polycrystalline Zn Electrodes in Acetone-Water $ZnSO_4$ Mixtures.	
0 2 8	"The Ion Exchange Theory of the Glass Electrode", CA59-4-8/19/63-3533e.	
0 2 9	"Oscillographic Polarography of Organic Compounds in Anhydrous $NH_4NO_3 \cdot nNH_3$", CA59-4-8/19/63-3547b.	

Log of Report Numbers

Card Col. 4 5 6	Report On:	Column 3 Code Entry 1
0 3 0	"Electrochemical Properties HBr in Isoamyl Alcohol", CA59-4-8/19/63-3549f.	
0 3 1	"Permeability of Halide Ions Across Ion-Exchange Membranes", CA59-4-8/19/63-3550a.	
0 3 2	"Determination of Thin Membrane Resistance During Ion Exchange with D.C.", CA59-4-8/19/63-3550c.	
0 3 3	"Electrochemical Properties of the Ion Exchange Membranes Junction", CA59-4-8/19/63-3550f.	
0 3 4	"E.M.F. of Galvanic Cells Containing Ion Exchange Membranes", CA59-4-8/19/63-3551c.	
0 3 5	"Electrolytic Purification of Organic Solvents from Ionic Impurities and from Water", CA59-4-8/19/63-3551f.	
0 3 6	"Coordination Effects are Classified", I&EC, 55, No. 9, 14(1963), C&EN 8/26/63, pg.34.	
0 3 7	"Method for the Determination of x, n and I_0", CA59-5-9/2/63-4777d.	
0 3 8	"Anodic Dissolution of Calcium in N,N-Dimethylformamide", CA59-5-9/2/63-4778d.	
0 3 9	"Standard Electrode Potentials in Mixed Solvents and Hydration of Ions", CA59-5-9/2/63-4787g.	
0 4 0	"The Electrolytic Reduction of Dicyandiamide. An Experimental Approach to the Difference in the Courses of Electrolytic Reduction", CA59-5-9/2/63-4790c.	
0 4 1	"Electrochemical Study of Solutions of $AlCl_3$ and Some of its Complexes in Nitro-Methane", CA59-6-9/2/63-4791a.	
0 4 2	"Current Generator Cells", CA59-5-9/2/63-4798c.	

Log of Report Numbers

Card Col.		
4 5 6	Report On:	Column 3 Code Entry 1
0 4 3	"Theoretical and Experimental Aids for the Elucidation of Electrochemical Synthesis Reactions," CA-59-7-9/30/63-7157 c.	
0 4 4	"Transport Processes at Electrodes," CA-59-7-9/30/63-7161g.	
0 4 5	"Electrosulfurizing," CA-59-7-9/30/63-7162e.	
0 4 6	"Recent Achievements in the Realm of Chemical Sources of Current,"CA-59-6-9/16/63-6033g.	

Card Col.	
4 5 6	Report On:
1 7 9	"Electrical Conductivity of Some Glassy $AsS_xSe_yGe_z$," V. N. Timofeyeva and A. U. Borisova, Seriya fiziki i khimii, No. 4, pp. 155-159 (1962) as found in English Abstracts of Selected Articles from the Soviet Bloc and Mainland China, Technical Journals, Series II, Chemistry, p. 5 (Oct. 1963).
1 8 0	"Electrical Conductivity of the Glassy System Arsenic-Selenium-Gallium," Z. U. Borisova and A. I. Bobrov, Seriya fiziki i khimii, No. 4, pp. 159-164 (1962) as found in Ibid., p. 8.
1 8 1	"Kinetics of Propylgallate Autooxidation in Aqueous Solution," L. S. Vartanyan, L. M. Strigun, and N. M. Emanuel', Doklady, Vol. 148, No. 1, pp. 97-100 (1963) as found in Ibid., p. 19.
1 8 2	"Dipole Moments of the Diphenyl Nitrogen Oxide Radical and of the Diphenyl Hydroxylamine Molecule," A. L. Bcuhachenko, Ye. N. Gur'yanova, L. A. Kalashnikova, M. G. Neyman, Doklady, Vol. 148, No. 1, pp. 95-96 (1963) as found in Ibid., p. 20.
1 8 3	"Method of Producing a Complex-Forming Cationite for the Selective Substitution of Alkali Metals," Budimir Veruovic, Referativnyy zhurnal khimiya, No. 23, p. 745 (1962) as found in Ibid., p. 82.
1 8 4	"Synthesis of Organoaluminum Compounds. II. Reaction of Metallic Aluminum with Alkyl Chlorides in the Gas Phase," Stanislow Pasynkiewicz, Wlodzimierz Dahlig, Jozef Ciemniewski, Referativnyy zhurnal khimiya, No. 22, Abstract 22Zh227, p. 224 (1962) as found in Ibid., p. 99.
1 8 5	"Spectroscopic Criterion for the Coordination of Aluminum in Anion Skeletons," V. A. Kolesova, Otdeleniye khimicheskikh nauk, No. 11, pp. 2082-2084 (1962) as found in Ibid., p. 132.
1 8 6	"The Welding of Teflon and Other Polymeric Materials by the Localized Action of Neutron Irradiation," I. M. Barkalov, V. I. Gol'danskiy, B. G. Dzantiyev, and Ye. V. Yegorov, Trudy II Vsesoyuznogo soveshchaniya po radiatsionnoy khimii, pp. 616-620 (1962) as found in Ibid., p. 165.

Log of Report Numbers

Card Col.	Report On: Column 3 Code Entry 5
0 6 6	"Rationale of the Transfer Coefficients of Electrode Kinetics," Pierre van Rysselberghe, Electrochim. Acta 8 (9), pp. 709-710 (1963) as found in Chemical Abstracts, Vol. 59, No. 10, p. 10985 a (November 1963).
0 6 7	"Anhydrous Electric Battery," Carl Horowitz and Thomas Breiner (to Yardney International Corporation) as found in Ibid., p. 0091 f.
0 6 8	"Galvanostalametry: A New Technique, Based on the Negative Pressure of Liquids, for Investigating Electrochemical' Phenomena at an Electrode," John L. Sligh and Abner Brenner, Journal of Electrochemical Society 110 (11), pp. 1136-42 (1963) as found in Chemical Abstracts, Vol. 59, No. 11, p. 12397 a (November 1963).
0 6 9	"Possible Use of Gallium as Negative Electrode in Galvanic Cells," D. Jahn and H. G. Plust, Nature 199 (4895), pp. 806-807 (1963) as found in Chemical Abstracts, Vol. 59, No. 12, p. 13594 e (December 9, 1963).
0 7 0	"Delayed Activation Battery," Milton Comanor and Charles M. Gold (to Yardney International Corporation) as found in Ibid., p. 13603 f.
0 7 1	"Sensor Apparatus for Primary Battery System," Nathan Gilbert (to United States Dept. of the Navy) as found in Chemical Abstracts, Vol. 60, No. 1, p. 200 g (January 6, 1964).
0 7 2	"Carbon Blacks for Organic Depolarized Batteries," G. S. Lozier and J. B. Eisen, Proceedings of the Annual Power Sources Conference, pp. 149-52, (1963) as found in Chemical Abstracts, Vol. 60, No. 4, p. 3714 h (February 17, 1964).
0 7 3	"Perchlorate Reserve Batteries," Howard R. Knapp and Achille L. Almerini, Proceedings of the Annual Power Sources Conference, pp. 125-8 (1963) as found in Ibid., p. 3715 c.
0 7 4	"New Organic Depolarizers," E. A. McElhill, D. L. Williams, and B. A. Bruber, Proceedings of the Annual Power Sources Conference, pp. 145-8 (1963) as found in Chemical Abstracts, Vol. 60, No. 5, p. 5069 f (March 2, 1964).

Log of Report Numbers

Card Col. 4 5 6	Report On:	Column 3 Code Entry 6
0 0 1	"The Sorret Effect as a Source of Error in Conductance Measurements," J. Phys. Chem., Vol. 65, No. 7, p. 1277, Stokes.	
0 0 2	"Solubility and Conductivity of Substituted Ammonium Iodides in Pentaborane," J. Phys. Chem., Vol. 65, No. 8, p. 1447. Slick-Wirth.	
0 0 3	"Polarizabilities and Molar Volumes of a Number of Salts in Several Solvents at 25°," J. Phys. Chem., Vol. 65, No. 8, p. 1465, Gilbertson-Stewart.	
0 0 4	"Theoretical Pathways for the Reduction of N_2 Molecules in Aqueous Media; Thermodynamics of N_2H_n," J. Phys. Chem., Vol. 64, No. 7, p. 833, Bauter.	
0 0 5	"Dissociation Constant and Limiting Conductance of LiBr in Liquid SO_2 at 0.22°: Evidence for the Solvation of Li^+," J. Phys. Chem., Vol. 64, No. 7, p. 945, Lichtin-Rao.	
0 0 6	"Spectroscopic Evidence of an Alumina Catalyzed Surface Reaction Between Ammonia and Carbon Disulfide," J. Phys. Chem., Vol. 64, No. 7, p. 955, Parry-Rubalcava.	
0 0 7	"Hydrogen Overpotential on Cadmium," J. Phys. Chem., Vol. 64, No. 5, p. 558, Ammar-Hassanein.	
0 0 8	"Electric Properties of Macromolecules. V. Theory of Ionic Polarization in Polyelectrolytes," J. Phys. Chem., Vol. 64, No. 5, p. 605, O'Konski.	
0 0 9	"Lithium Salts as Solutes in Non-Aqueous Media. I. The Ternary System $LiNO_3$ - $LiClO_4$ - CH_3OH at 25°," J. Phys. Chem., Vol. 64, No. 5, p. 670.	
0 1 0	"Electrochemistry of Crystal-Polymer Membranes. Part I. Resistance Measurements," J. Phys. Chemistry, Vol. 64, No. 4, p. 417, Barrer-James.	

Log of Report Numbers

Card Col. 4 5 6	Report On: Column 3 Code Entry 6
0 1 1	"Electrochemistry of Crystal-Polymer Membranes. Part II. Membrane Potentials," J. Phys. Chem., Vol. 64, No. 4, p. 421, Barrer-James.
0 1 2	"Measurement of the Surface Potentials of Metals Due to Absorption of Organic Compounds from Solution," J. Phys. Chem., Vol. 64, No. 4, p. 427, Gottlieb.
0 1 3	"The System Lithium Hydride - Lithium Fluoride," J. Phys. Chem., Vol. 64, No. 4, p. 503, Messor-Mellor.

Log of Report Numbers

Card Col. 4 5 6	Report On: Column 3 Code Entry 6
0 1 4	"Coulostatic Method for the Kinetic Study of Fast Electrode Processes. I. Theory," Journal of Physical Chemistry, Vol. 66, No. 11, p. 2204, Delahay.
0 1 5	"Monolayer Permeability and the Properties of Natural Membranes," Journal of Physical Chemistry, Vol. 66, No. 10, p. 1911, Blank.
0 1 6	"Conductance of 2-2 Electrolytes with Multiple Charge Sites," Journal of Physical Chemistry, Vol. 66, No. 9, p. 1749, Lind and Fuoss.
0 1 7	"Hydrazinium Bromide as a Solvent," Journal of Physical Chemistry, Vol. 66, No. 6, p. 1125, Seward.
0 1 8	"The Ionization Potential of Hydrogen Disulfide (H_2S_2)," Journal of Physical Chemistry, Vol. 66, No. 6, p. 1214, Kiser and Hobrock.
0 1 9	"Oxide-Coated Electrodes. I. Aluminum in Acid Solutions," Journal of Physical Chemistry, Vol. 66, No. 5, p. 866, Plumb.
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0 0 9	"Electrochemistry of Fuel Cell Electrodes," A. C. Mannder, Tyco, Inc., PIC 742, Revision 2 (October 1963).
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APPENDIX

IDENTIFICATION OF ION-EXCHANGERS, SEPARATORS, AND MATERIALS OF CONSTRUCTION

Gelman Instrument Company, Ion-Exchange Membranes, "Acropor":

SB-6407 on Nylon

WA-6402 on Nylon

WB-6403 on Nylon

SA-6404 on Nylon

WA-6406 on Viscose

Ionac Chemical Company, Ion-Exchange Membranes:

MC-3142 Cation Membrane

MA-3148 Anion Membrane

XLMC-3235 Cation Membrane

XLMA-3236 Anion Membrane

Rohm and Haas Company:

LA-1 Liquid Ion-Exchanger - Anion - "Amberlite"

Whatman Ion Exchange Membranes:
Manufactured by W. & R. Balston, Ltd., England

Anion Exchanger - Ecteola Cellulose	Paper ET 20
Anion Exchanger - Aminoethylcellulose	Paper AE 30
Anion Exchanger - Diethylaminoethylcellulose	Paper DE 20
Cation Exchanger - Cellulose Phosphate	Paper P 20
Cation Exchanger - Carboxymethylcellulose	Paper CM 50

American Machine and Foundry Company, "AMFion" Products:

C- 60 Ion-Permeable Membrane, Strong Acid Type

C-103c Strong Acid Type

Arthur H. Thomas Company, Filter Paper:

Whatman No. 42

IDENTIFICATION OF ION-EXCHANGERS, SEPARATORS, AND MATERIALS OF CONSTRUCTION

Continued

Webril Non-Woven Fabrics, Kendall Company, Walpole, Massachusetts:

EM-470 Dynel

M-1216 Viscose - Vinyon Binder

M-1231 Viscose - Chandler Binder

M-1365 Cotton-Chandler Binder - Balance Acetate

M-1406 Nylon - Dynel Binder

EM-476 Polypropylene

R-2205 Pure Cellulose

Polypropylene Sheet - 0.020" Thick

Polyethylene Sheet from Bag Stock

Nalco Chemical Company:

D-30 Vinyl Type Dialysis Membrane

Whitehead Metal Products Company, Inc.:

Alcoa Aluminum Alloy Sheet No. 3003-H114

Laminated Shim Company, Inc.:

Stainless Steel Sheet - Type 302 - 0.002" Thick

Plastic and Rubber Products Company (available from Beemer Engineering Co.):

"O" Rings - Compound No. 488-70 - Nitrile Rubber - Good for NH_3

"O" Rings - Compound No. 805-70 - Butyl Rubber - Good for SO_2

Belden Manufacturing Company:

No. 8530 Tin Plated Solid Copper Wire - Vinyl Insulation - MW-C-22-(1) U

L. Frank Markel and Sons:

C-20381 - Silver Plated Solid Copper Wire, 24 Gauge, Teflon Insulation

IDENTIFICATION OF ION-EXCHANGERS, SEPARATORS, AND MATERIALS OF CONSTRUCTION

Continued

Allied Chemical Corporation, General Chemical Division, Film:

Aclar 33C, $\frac{1}{2}$ mil thickness (Fluorohalocarbon Resin)

Armstrong Products Company:

A-12 Epoxy Resin Adhesive

Devcon Corporation:

Clear Epoxy Adhesive

A. R. Purdy Company, Inc. :

Magnesium Alloy No. AZ31B0
96% Mg + 3% Al + 1% Zn

Polymer Corporation of Pennsylvania:

Nylon Rod

General Electric Company:

RTV-11 Silicone Rubber

TABLE I

IDENTIFICATION OF SOLVENTS

		Stock or Lot No.	Catalog No.
Acetonitrile	Matheson, Coleman & Bell, Practical Grade**	P-2726	AX150
Acetone	J. T. Baker Chemical Co., Analyzed Reagent, 99.5% Pure	22932	9006
Amberlite LA-1	Rohm & Haas Company	6881	----
Benzene	Fisher Scientific Co., Certified, 99 Mol % Pure	732469	B-414
n-Butylamine	Fisher Scientific Co., Certified, 99.5%	722837	B-415
Butyrolactone	Antara Chemicals Div., General Aniline & Film Corp.	11-72707	R-773
p-Chloro benzotrifluoride	Hooker Chemical Corp.	----	Ord. 63-1533
Cyclohexanone ("Nadone")	National Aniline Div., Allied Chemical Corp.	Spl. #3438	----
p-α-Dichlorotoluene	Eastman Organic Chemicals, Practical*	----	P-1103
N, N-Dimethylformamide	Matheson, Coleman & Bell	5974	DX 1730
2-Ethanolpyridine	Reilly Tar & Chemical Co., 95% Minimum Purity	----	----
Ethyl Acetate	Merck & Co., Inc., 90% Ethyl Acetate, U.S.P. VIII	62672	0561
1-Fluoro-2, 4-dinitrobenzene	Eastman Organic Chemicals	----	6587
p-Fluorotoluene	Eastman Organic Chemicals	----	2969
Freon 11	The Matheson Co., Inc., 99.9% Minimum purity	----	----
Freon 113	The Matheson Co., Inc., 99.0% Minimum purity	----	----
Freon 114	The Matheson Co., Inc., 95.0% Minimum purity	----	----
Genesolv-D	General Chemical Division, Electronic Grade***	K-909006	----
Hexylene Glycol	Union Carbide Chemicals Co.	S 262660	----
iso-Propylamine	Matheson, Coleman & Bell	5 470	PX 1845
Mercaptopropionic Acid	Evans Chemetics, Inc., 100% Assay	643-397	----

TABLE I Continued

IDENTIFICATION OF SOLVENTS

		Stock or Lot No.	Catalog No.
Methanol	Merck & Co., Inc., Reagent Methyl Alcohol, Anhydrous, A. C. S.	61763	7168
N-Methyl-2-Pyrrolidone	Antara Chemicals Div., General Aniline & Film Corp.	----	----
Nitromethane	Matheson, Coleman & Bell, Practical	P-1240	NX 615
Petroleum Ether	J. T. Baker Chemical Co., Analyzed Reagent (20 - 40° C.)	25825	9272
n-Propylamine	Eastman Organic Chemicals	----	1216
Propylene Carbonate	Eastman Organic Chemicals, Practical Grade	----	P-7050
Pyridine	Fisher Scientific Co., Certified Reagent, A. C. S.	732238	P-368
Silicone Oil, DC-200	Dow Corning Corp.	----	----
Tetrahydrofuran	Matheson, Coleman & Bell	5962	TX-280
Toluene	Fisher Scientific Co., Certified Reagent, A. C. S.	733991	T-324
Triallylamine	Shell Chemical Co.	----	----
Trichlorobenzene	Eastman Organic Chemicals	----	1801
	Matheson, Coleman & Bell	9193	TX 1067
(1, 1, 1) Trichloroethane	Fisher Scientific Co., purified, inhibited	783937	T-398
Xylene	J. T. Baker Chemical Co., Analyzed Reagent, A. C. S.	22458	9490

*Eastman Organic Chemicals, Dept., Distillation Products Industries, Div. of Eastman Kodak Co.
**Div. of The Matheson Co., Inc.
***Div. of Allied Chemical Co.

TABLE II

IDENTIFICATION OF SOLUTES

		Lot No.	Cat. No.
$AlCl_3$	Fisher Scientific Co., Anhydrous Certified Reagent	723393	A 575
AlF_3	Olin Mathieson Chemical Corp., Anhydrous Grade	0659088	---
$Al_2(SO_4)_3$	J. T. Baker Chemical Co., U. S. P.	20439	---
$(CH_3)_4NCl$	Eastman Organic Chemicals*	---	3592
$(CH_3)_4NI$	Eastman Organic Chemicals*	---	2434
$(CH_3)_3N\cdot HCl$	Eastman Organic Chemicals*	---	265
KBr	Fisher Scientific Co., Certified Reagent	720110	P 205
$KF\cdot 2H_2O$	J. T. Baker Chemical Co., Analyzed Reagent	25010	3122
KI	J. T. Baker Chemical Co., U. S. P.	25291	3168
KSCN	Fisher Scientific Co., Certified Reagent, A. C. S.	730253	P-317
LiCl	Fisher Scientific Co., Certified Reagent	724595	L-121
LiF	J. T. Baker Chemical Co., Analyzed Reagent	23101	2380
$MgBr_2\cdot 6H_2O$	Matheson, Coleman and Bell Reagent**	3041442	MX 30
$MgSO_4\cdot 7H_2O$	J. T. Baker Chemical Co., Analyzed Reagent	---	2500
NaBr	J. T. Baker Chemical Co., Analyzed Reagent	25289	3588
NaCl	Merck & Co., Inc., Reagent, A. C. S.	60452	7407
NaI	Merck & Co., Inc., U. S. P.	61163	5080
$NH_2OH\cdot HCl$	Eastman Organic Chemicals, 95-98%, Practical	---	P 340

*Eastman Organic Chemicals Department,
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